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Field Evaluation of a Swirl Degritter at Tamworth, New South Wales, Australia

G. J: Shelley
Cammeray (Australia)

Prepared for

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16. ABSTRACT

This field evaluation program was initiated with the overall objective of providing information on the behaviour of a full scale swirl degritter designed and constructed in accordance with the shapes and proportions developed during model studies.

The swirl degritter was designed for the pre-treatment of river water prior to its entrance into the rising main in order to reduce wear and tear on the raw water pumps and also to reduce the solids loading of the rising main and that of the balance tank of the water treatment works.

Results of the solids removal had been evaluated in terms of three parameters : solids larger than 0.2 mm - the classical size aimed at in grit chambers -, solids larger than 0.088 mm and total settleable solids. In general the tests proved the validity of the laboratory results and at design flowrates 98% removal efficiencies were achieved.

Tests at flowrates higher than the design showed slightly better efficiencies than predicted.

The field evaluation tests carried out at Tamworth, New South Wales, Australia, prove the validity of the system in terms of its hydraulic efficiency. Compared with a conventional constant velocity longitudinal flow grit chamber the construction cost is halved, operational and maintenance costs are considerably lower.

This report was submitted in fulfillment of the conditions of Grant No R806746, by G.J. Shelley, Consulting Engineer, under the sponsorship of the U.S. Environmental Protection Agency. The report covers the period between March 11, 1980 and June 4, 1980 and the work was completed as of October 27, 1980.

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By

G.J. Shelley
P.B. Stone
A.J. Cullen

G.J. Shelley, Consulting Engineer
Cammeray, NSW, Australia 2062.

Grant No. R-806746

Project Officers:

Richard Field
Hugh Masters

Storm and Combined Sewer Section
Wastewater Research Division
Municipal Environmental Research Laboratory (Cincinnati)
Edison, New Jersey 08817

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies and to minimise the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

The study describes the evaluation of a swirl degritter to perform the function of grit separation more effectively than the conventional units for concentrated grit.

Francis T. Mayo
Director
Municipal Environmental Research
Laboratory

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ABSTRACT

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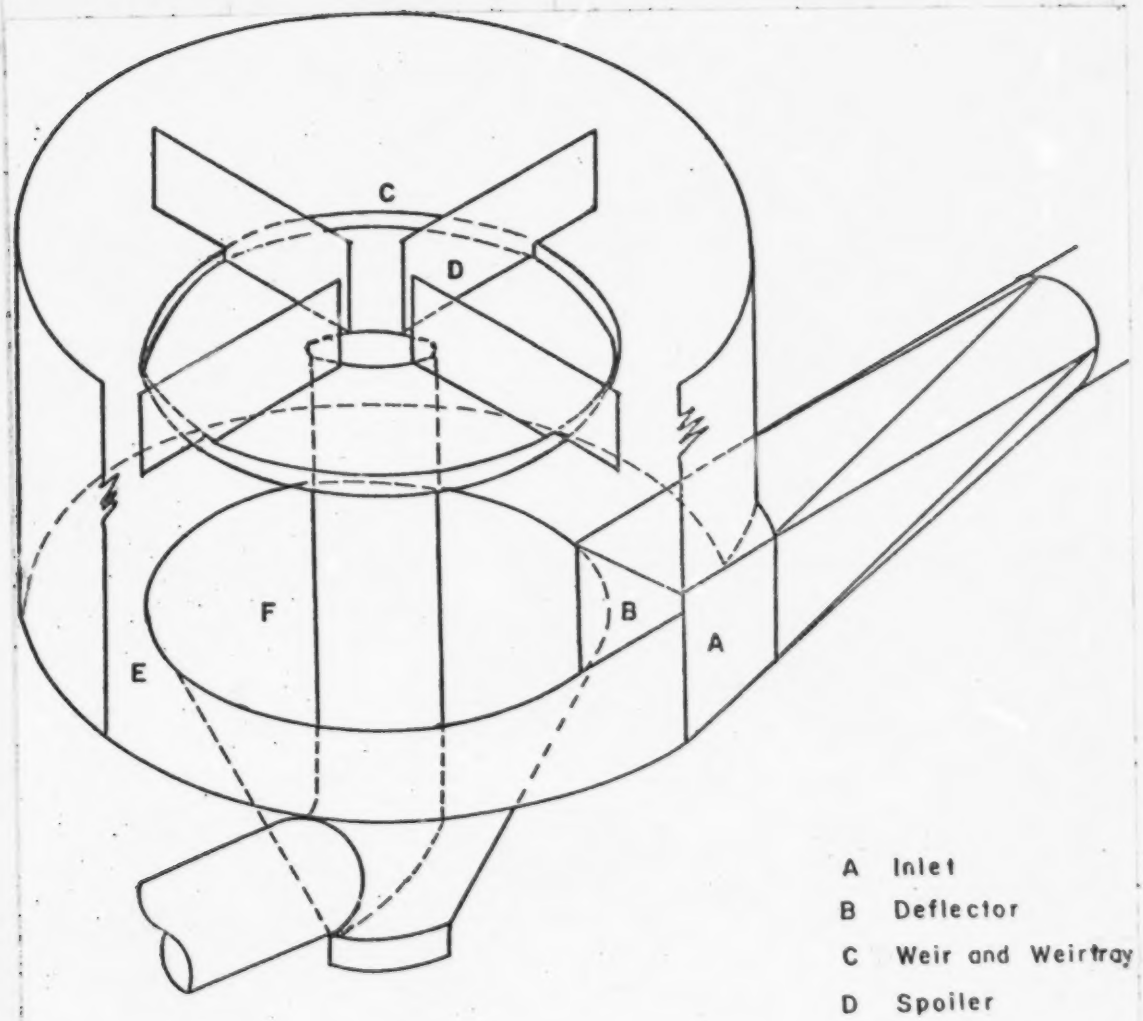

FIGURE 1 SWIRL DEGRITTER ISOMETRIC VIEW

SECTION 1

INTRODUCTION

A considerable number of Australian towns rely on rivers of widely varying flows for their water supply.

River flows are generally of low stage for most of the year, however withdrawals of water may also be required during periods of high flow. The rivers are polluted to varying degrees with both organic and inorganic matter and the removal of this pollution is essential for obtaining potable water.

The arrangement of the works is governed by the topography of the site, with the intake being located either in the bed or on the bank of the river and the raw water pumping station on the flood plain. The water gravitates to the pumping station and is then pumped to a water treatment plant which in turn supplies the storage reservoirs.

The necessity for the withdrawal of water from the river at any stage of flow results in varying rates of pollution entering the system. Difficulties have been experienced with the settlement of solids in the suction lines and also with the excessive wear on the raw water pumps due to the sand content of the water.

The Department of Public Works of New South Wales, one of the main water supply design authorities of this State has, therefore, decided that systems exposed to these hazards shall include an initial treatment of raw water. This pre-treatment is intended to remove the sand which has been causing significant maintenance and operational problems.

The first project where such problems were foreseen was at Tamworth, a town at about 280 mi (450 km) north of Sydney.

During the preliminary planning and design stages comparisons were made between the conventional longitudinal flow, constant velocity grit chamber and other known solid liquid separation systems. Sketch designs were prepared and capital and maintenance costs were compared.

The swirl degritter was chosen because of its considerably lower capital and maintenance costs.

The swirl degritter was constructed during 1979 and 1980. The field evaluation of this structure aimed to determine the efficiency of removal of

solids and to compare the results with those obtained from the design manual (Ref. 1) and the prototype testing at Denver, Col., U.S.A. (Ref. 2).

Due to the low solids content of the river water during the testing period, samples with significant solids content could generally be recovered only from the runs which included sand artificially added. During some runs settling and scouring occurred in the influent conduit resulting in a random distribution of solids in the vertical cross-section of the intake conduit. In these cases we could not determine concentration of solids in the influent in a reliable and consistent manner and, therefore, these runs had to be also eliminated from the final evaluation.

Removal efficiency rates could be determined for:

total solids
solids larger than 0.088 mm
solids larger than 0.2 mm

SECTION 2

CONCLUSIONS

The swirl degritter removes efficiently that portion of the solids for which it was designed.

The removal efficiency rate of the inorganic material larger than 0.2 mm diameter and having a density of 2650 kg/cu.m. (specific gravity : 2.65) of the five metre (16ft 5in) diameter unit was in substantial agreement with the predictions based on model testing and scale up using the settling velocities and the Froude number.

The method of removing grit collected in a hopper allows for complete automation of operation and the possibility of an unattended plant with remote control.

The capital cost of installation of the swirl degritter is about half of that of a conventional longitudinal flow, constant velocity grit chamber.

The operational costs depend on the quantity of solids collected in the hopper. Maintenance costs are low because there are no mechanical, moving elements.

SECTION 3

RECOMMENDATIONS

The swirl degritter in its present form has produced the predicted results.

The departures from the original form of the swirl chamber were necessitated by the particular application, and may not be required in other cases.

It is, therefore, recommended that

a. the swirl degritter be designed in accordance with the proportions and dimensions that are recommended in Ref. 1.

b. the design include facilities for monitoring the performance.

c. the inspection of the chamber, inlet and outlet conduits and of the monitoring equipment be made convenient.

d. provision be made for controlled adding of solids - if accelerated monitoring of performance is envisaged.

e. further work be conducted to determine the ability of the degritter to classify materials on the bases of size and specific gravity (density).

SECTION 4

DESCRIPTION OF THE SYSTEM

BASIC INFORMATION

The swirl degritter is part of the River Intake Works of the Tamworth Water Supply Augmentation project. Planning design and construction was jointly financed by the Public Works Department of New South Wales and Tamworth City Council. Detail design and contract documentation was prepared by G. J. Shelley, Consulting Engineer. The construction was supervised by the Public Works Department of N.S.W. and carried out by John Holland (Constructions) Pty. Ltd.

SITE CONDITIONS

The intake works is about 3mi (4.5 km) west of Tamworth on the flood plains of the Peel River. The water of the river at Tamworth consists partly of natural run off from forests and grazing land and of releases from the Chaffey Dam.

The water for Tamworth City is withdrawn through an intake structure consisting of a side inlet weir combined with a tapered channel in the bed of the river. The conduit connecting the Intake Structure with the swirl degritter has a 2ft 6in x 2ft 6in (760 x 760mm) reinforced concrete rectangular section approximately 89ft (27 m) long, ending in a structural steel rectangular section inside the swirl degritter. The effluent from the swirl degritter flows by gravity to the pumping station through mild steel lined circular conduits. From the pumping station the raw water is pumped to the water treatment works through a 1.5 mi (3 km) long rising main. (Figures 2 and 3)

FLOW RATES, VELOCITIES OF FLOW

The rate of flow through the system is governed by the variable speed pumps. The speed and the delivery rate of pumps is automatically set by telemetry depending on the water level in the balance tank of the water treatment works and the available supply from the river.

A single pump satisfies the demand of 3.4 to 10.8 US Mgal/d (0.15 - 0.55 cu.m/s) and two pumps work in parallel at delivery rates of 10.3 to 20.5 US Mgal/d (0.45 - 0.9 cu.m/s).

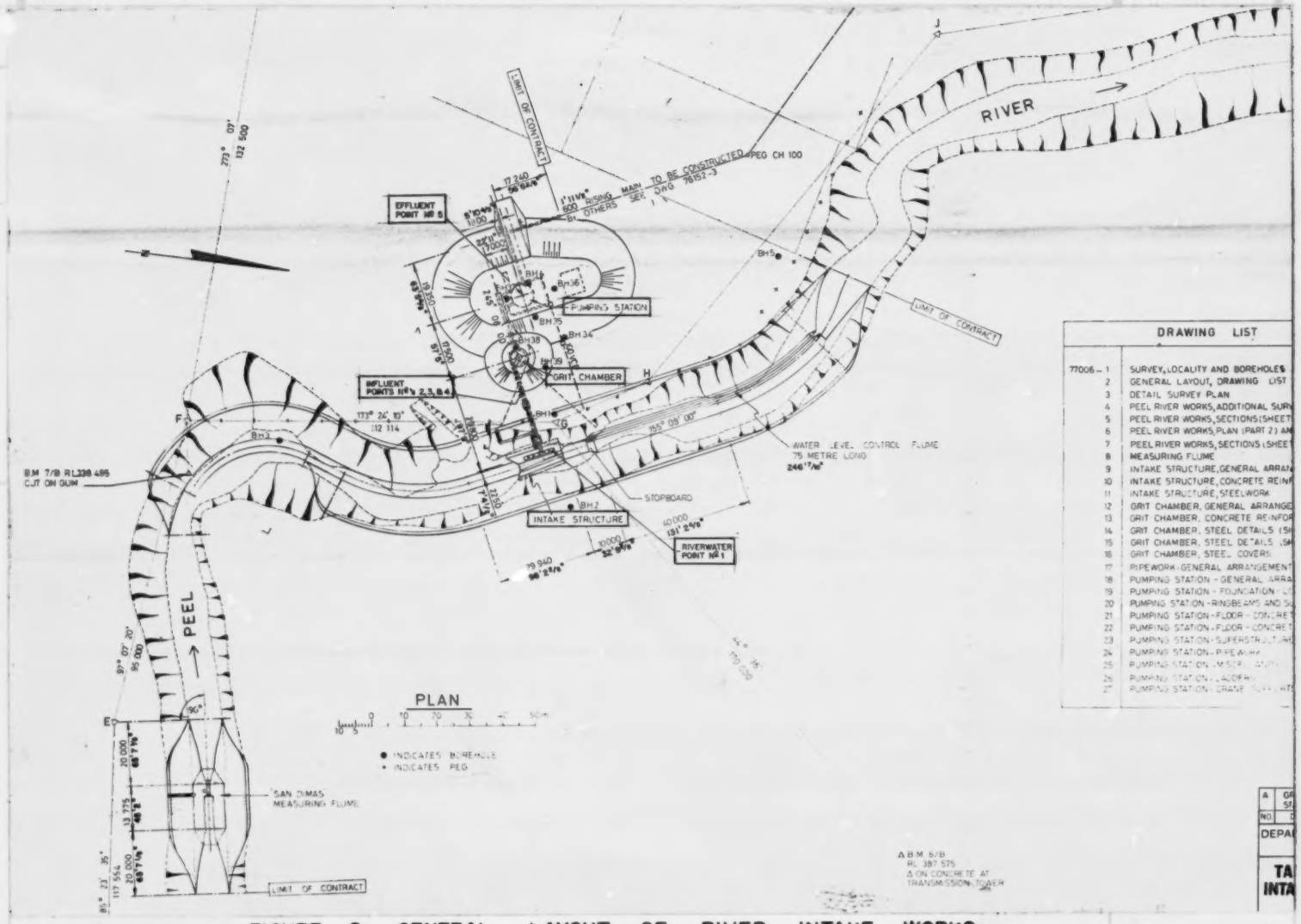
RIVER
PEEL
LIMIT OF CONTRACT
EFFLUENT POINT NO 5
PUMPING STATION
GRIT CHAMBER
INFLUENT POINTS Nos 2,3,&4
INTAKE STRUCTURE
RIVERWATER POINT NO 1
STOPBOARD
WATER LEVEL CONTROL FLUME 75 METRE LONG
246 1/2"
SAN DIMAS MEASURING FLUME
B.M 7/B RL 238 495 CUT ON GUM
Δ B.M. 6/B RL 387 575 Δ ON CONCRETE AT TRANSMISSION TOWER
PLAN
INDICATES BOREHOLE
INDICATES PEG
DRAWING LIST
77006 – 1 SURVEY, LOCALITY AND BOREHOLES
2 GENERAL LAYOUT, DRAWING LIST
3 DETAIL SURVEY PLAN
4 PEEL RIVER WORKS, ADDITIONAL SURV
5 PEEL RIVER WORKS, SECTIONS (SHEET
6 PEEL RIVER WORKS, PLAN (PART 2) AN
7 PEEL RIVER WORKS, SECTIONS (SHEET
8 MEASURING FLUME
9 INTAKE STRUCTURE, GENERAL ARRAN
10 INTAKE STRUCTURE, CONCRETE REINF
11 INTAKE STRUCTURE, STEELWORK
12 GRIT CHAMBER, GENERAL ARRANGE
13 GRIT CHAMBER, CONCRETE REINFOR
14 GRIT CHAMBER, STEEL DETAILS (SH
15 GRIT CHAMBER, STEEL DETAILS (SH
16 GRIT CHAMBER, STEEL COVERS
17 PIPEWORK - GENERAL ARRANGEMENT
18 PUMPING STATION - GENERAL ARRA
19 PUMPING STATION - FOUNDATION - L
20 PUMPING STATION - RINGBEAMS AND S
21 PUMPING STATION - FLOOR - CONCRE
22 PUMPING STATION - FLOOR - CONCRE
23 PUMPING STATION - SUPERSTRUCTURE
24 PUMPING STATION - PIPEWORK
25 PUMPING STATION - MISC. ALUM
26 PUMPING STATION - FLOORS
27 PUMPING STATION - CRANE RUNWAYS

FIGURE. 2. GENERAL LAYOUT OF RIVER INTAKE WORKS

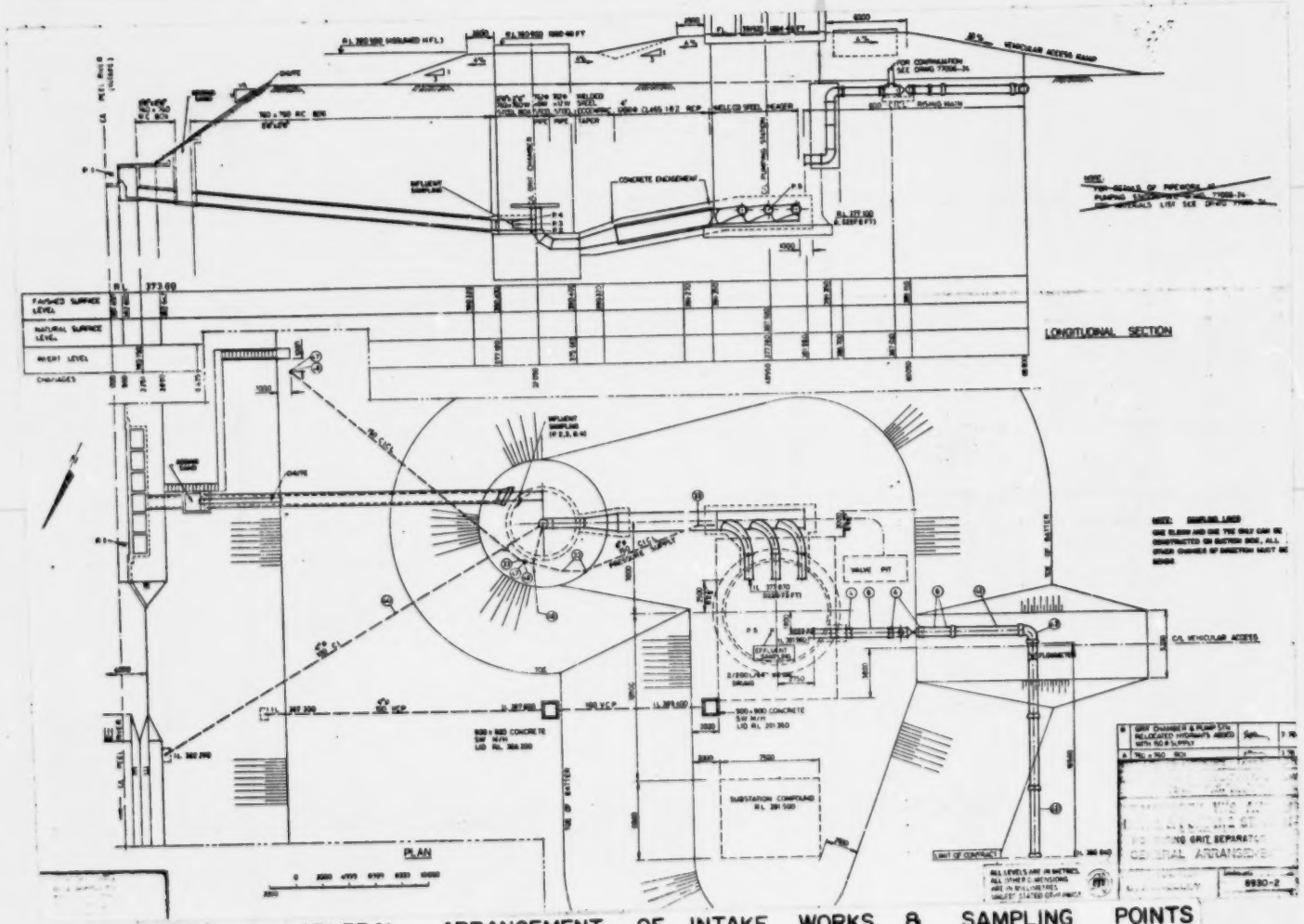

FIGURE. 3. GENERAL ARRANGEMENT OF INTAKE WORKS & SAMPLING POINTS

The velocities of flow in the influent box conduit varies between 0.85 and 5.11 fps (0.26 and 1.56 m/s) while in the effluent circular conduit it varies between 0.44 and 2.61 fps (0.13 and 0.8 m/s).

SUSPENDED LOAD IN WATER

The suspended load in the river depends on the stage of the flow which may result from either dam releases or from natural run off. It may consist of organic or inorganic solids.

SWIRL DEGRITTER

Main Dimensions

The swirl degritter was proportioned in accordance with Figures 12 and 3 of "The Swirl Concentrator as a Grit Separator Device" (EPA-670/2-74-026). (Ref. 1). There were three departures from the recommended structure. The weir was designed to be submerged at all times, a coverplate was placed on top of the spoilers, and a secondary spoiler was placed into the hopper. The first two measures were taken in order to positively avoid vortex formation and to prevent entrance of air into the section line of the pump. The secondary spoiler was placed into the hopper in order to reduce the circular movement of the water (Figure 4).

It is expected that during operation the flow rates vary between 3.4 US Mgal/d (0.15 cu.m/s) and 19.4 US Mgal/d (0.85 cu.m/s) and will be regulated by the delivery rates of the variable speed pumps.

The design allows for minimum water levels in the degritter to be associated with each pumping rate, varying approximately linearly, between 5ft 7in (1.71 m) above the weir (0.15 cu.m/s) and 5ft 4in (1.62 m) above the weir (0.85 cu.m/s). It is expected that for about 80% of the time, water levels in the degritter will exceed the minimum values and will be determined by the river levels.

Removal Of Collected Grit From Hopper

The grit collected in the bottom of the hopper is removed with a water jet eductor pump through a grit discharge pipeline back into the Peel River. In order to ensure proper solids concentration in the discharge line, originally twelve water jets were constructed in the hopper distributed along two rings, in addition to the six mixing jets operating from the body of the eductor pump. During the monitoring and testing period the six jets in the ring at about mid-height of the hopper were disconnected. The mixing water added into the hopper is approximately 30% of the grit discharge slurry flow. Both the mixing jets and the eductor pump are supplied on discharge side of the raw water pumps, from the rising main between the pumping station and the water treatment works.

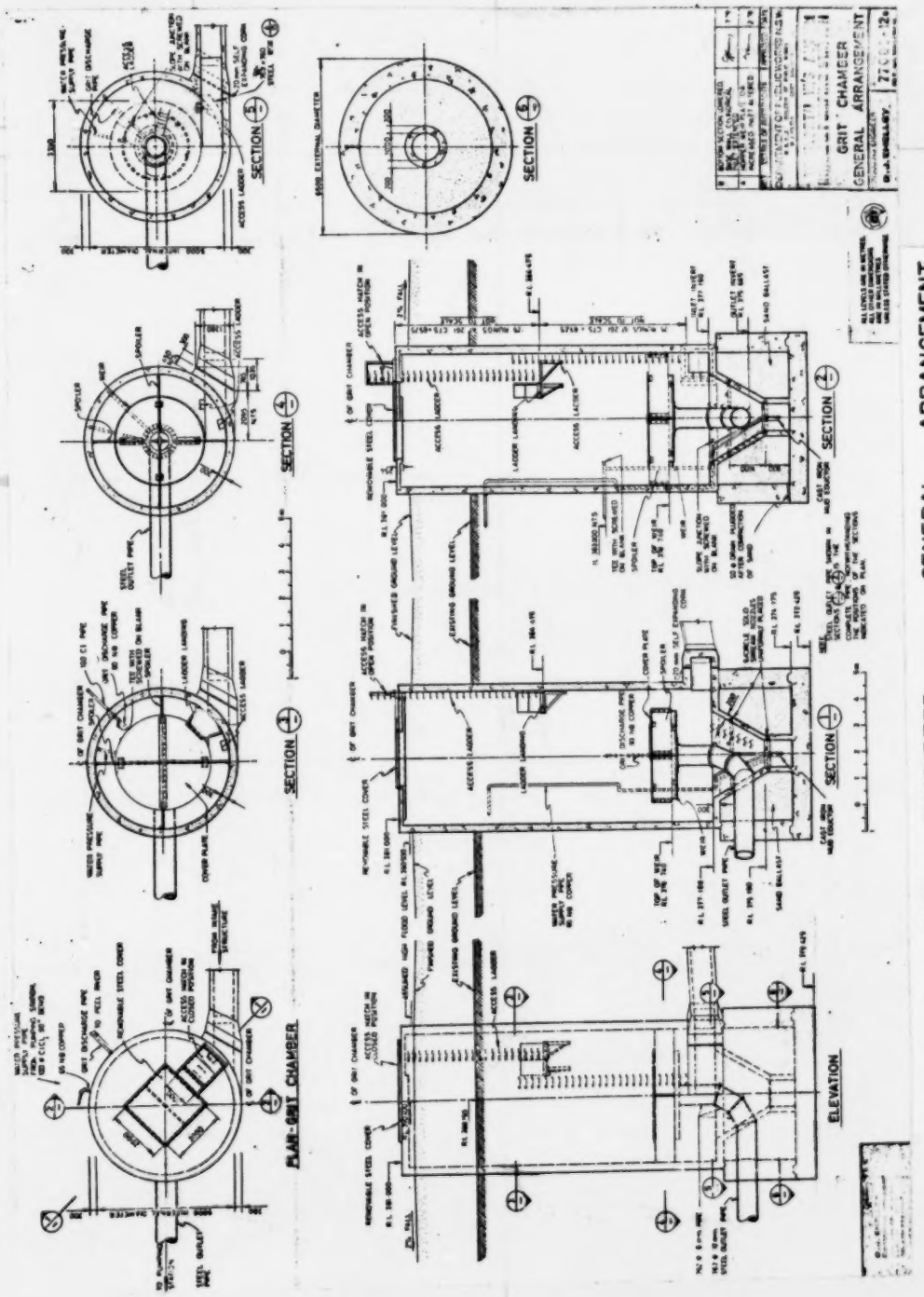

FIGURE 4. SWIRL DEGRITTER — GENERAL ARRANGEMENT

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SECTION 5

SAMPLING

SAMPLING POINTS AND SAMPLE SIZES

The sampling points and sample sizes are shown in Table 1.

TABLE 1. SAMPLING POINTS

Nº	Position	Liquid Sampled	Method	Size U.S. gal. (L) Runs	
				1 – 34	36 – 55
1	Intake works (in riverbed)	River water	Buckets	54(205)	54(205)
2	Influent conduit bottom	Influent liquid	Sampling port	54(205)	54(205)
3	" " center	" "	"	54(205)	54(205)
4	" " top	" "	"	54(205)	54(205)
5	Discharge of main pumps	Effluent liquid	slot	54(205)	108(410)

SAMPLING EQUIPMENT

Sampling Point No. 1

The sampling was carried out manually with buckets immersed into the river.

Sampling Points Nos. 2, 3 & 4

Sockets of UPVC (unplasticized PVC) conduit pipe turned against the main flow were used as sampling ports. The inside diameters of the sockets were 1.5in (39 mm). The centers of the ports were placed in the vertical center line of the conduit at 2.75in (70 mm), 1.25ft (380 mm) and 2.27ft (690 mm) distances respectively from the invert. Each sampling point was individually connected to the sampling pump with approximately 16ft (5 m) of 1.125in (29 mm) diameter rigid UPVC pipe. Stop cocks were provided at the suction end of the pump. The discharge line of the pump also consisted of a 1.125in (29 mm) diameter rigid UPVC

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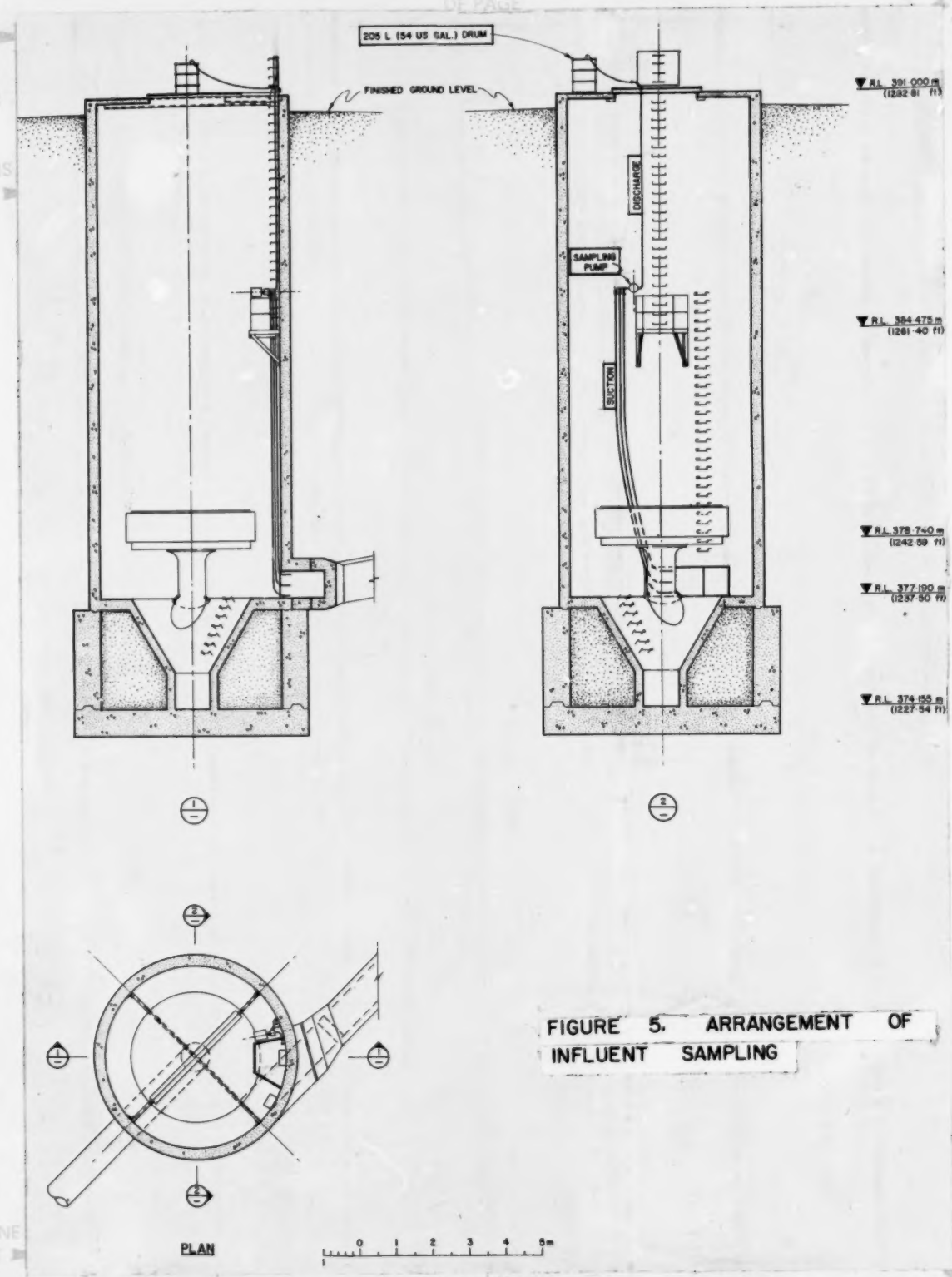

FIGURE 5. ARRANGEMENT OF INFLUENT SAMPLING

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pipe within the structure of the swirl degritter connected to a flexible polyethylene hose on the surface. The arrangement of this sampling system was altered after Run 34 by placing a 2in (50 mm) high sill between the bottom intake port and the invert of the conduit (sample included the rolling bedload) and a shorter and larger diameter flexible hose was used (sampling velocity increased) (Figure 5).

Sampling Point No. 5

The sampling intake was a slot cut into a 0.375in (10 mm) outside diameter copper tube (Figure 6) which penetrated into the 12in (300 mm) discharge pipe. A flexible hose was attached to the end of the copper tube. During Runs 1-34 the slot had an area of 0.93 sq.in (600 sq mm) and the center of the slot was at the center of the discharge pipe. During Runs 35-55 the area of the slot was reduced to about 0.6 sq.in (389 sq mm), the center of the slot was at about the top quarter point of the 12in (300 mm) diameter pipe and the flexible hose was shortened. The slot was always facing the direction of flow.

Sampling Containers

54 US gal (205 L) drums lined with removable semirigid polyethylene liners were used as temporary containers for each sample.

Sand

The particle size distribution of the sand added to the system is shown in Table 2 and Figure 7. A chute was constructed on the bank of the river ending at the manhole near the intake works (Figure 3). Before commencing sampling each run a quantity of sand measured by volume was placed into the chute. The sand was then manually added over a recorded period of time.

In chosing the sand we aimed at minimizing settlement of solids in the influent conduit and still being compatible with the limitations of the readily available laboratory equipment.

Rate of Supply from the Peel River

During the sampling period there had been no significant rainfall in the catchment area and the flow in the Peel River was completely dependent on the limited releases from Chaffey Dam.

During Runs 1 to 18 the operating pumps could only work during the time required for sampling because the pumping rate had been considerably higher than the supply in the river from upstream. This resulted in a "stop-go" flow through the intake and the system.

During Runs 19 to 34 the supply of water in the river was adequate and the flow through the system was continuous during working hours but

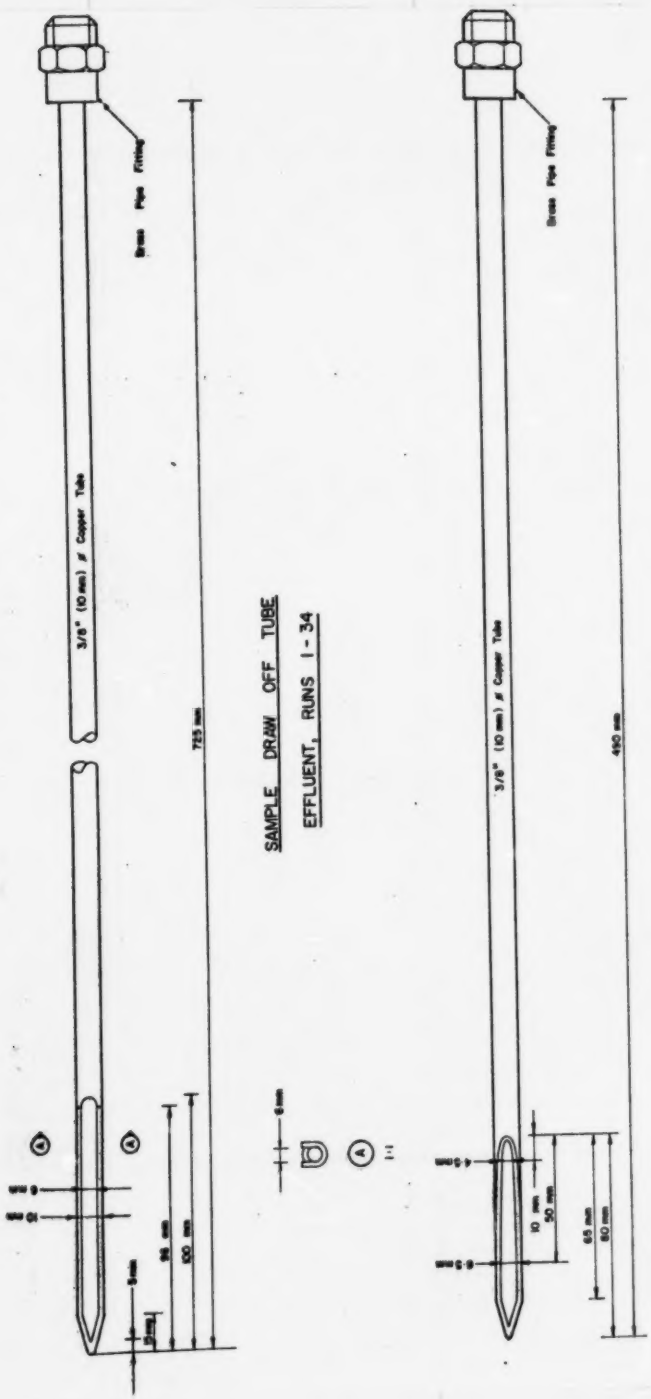

3/8" (10 mm) ø Copper Tube
Brass Pipe Fitting
735 mm
SAMPLE DRAW OFF TUBE
EFFLUENT, RUNS 1 - 34
3/8" (10 mm) ø Copper Tube
Brass Pipe Fitting
490 mm
SAMPLE DRAW OFF TUBE
EFFLUENT, RUNS 36 - 55

FIGURE. 6. SAMPLER AT POINT 5

TABLE 2. PARTICLE SIZE DISTRIBUTION OF SAND

Particle Size (mm) group			average	%	Cumulative %
	> 2·0			1·16	1·16
2·00	–	1·68	1·89	0·22	1·38
1·68	–	1·41	1·54	0·03	1·41
1·41	–	1·19	1·30	0	1·41
1·19	–	1·00	1·10	0·21	1·62
1·00	–	0·84	0·92	0·08	1·70
0·84	–	0·71	0·77	1·85	3·55
0·71	–	0·59	0·65	4·48	8·03
0·59	–	0·50	0·55	7·59	15·62
0·50	–	0·42	0·46	7·20	22·82
0·42	–	0·35	0·39	10·41	33·23
0·35	–	0·30	0·32	11·94	45·17
0·30	–	0·25	0·27	11·64	56·81
0·25	–	0·21	0·23	10·61	67·42
0·21	–	0·177	0·193	8·68	76·12
0·177	–	0·125	0·149	8·14	84·26
0·125	–	0·088	0·105	2·55	86·81
	< 0·088			13·20	100·01

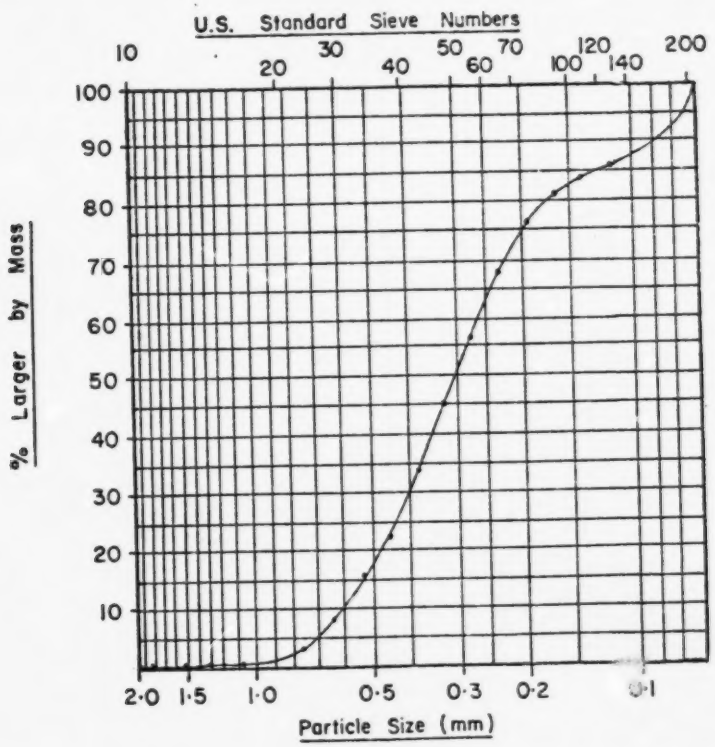


FIGURE 7. PARTICLE SIZE DISTRIBUTION OF SAND

was interrupted for lunch breaks and at night.

During Runs 36-55 the supply in the river was nearly adequate. The withdrawal of water had to be interrupted occasionally in between sampling runs particularly after some higher flow sampling.

Solids Content of River Water

The river water was sampled in Runs 1-3 only because it was found that it contained practically no solids (about 3.4 mg/L). These solids consisted of particles less than 0.088 mm diameter grain sizes.

An attempt was made to establish the organic solids content of the water from the three river samples collected and from a further three randomly chosen influent samples. The laboratory results indicated that the mass of the dry grit ash was only about 0.3 mg/L less than the dry mass of the total solids.

It may be assumed, therefore, that all the solids were artificially added to the influent and that they constitute a reasonably uniform material of a specific gravity of 2.65 (density of 2650 kg/cu m) and of a bulk density of 100 lb/cu ft (1500 kg/cu m).

Flow Rates and Velocities

During sampling the flowrate in the conduit was governed by setting the raw water pumps to predetermined speeds and the corresponding flow rate was read from the calibrated pump performance curve. The velocity of flow was calculated from the flow rate and the area of the conduit.

INFLUENT SAMPLING

The sampling pump used for Points No. 2, 3 and 4 worked at constant speed and the sampling velocity had been determined from the time required to fill a 54 US gal (205 L) drum and the net area of the sampling port. The intake velocities were 2.8 fps (0.85 m/s) for Runs 1-34 and 4.5 fps (1.37 m/s) for Runs 36-55. These sampling velocities were adequate for capturing and transporting the largest sand particles introduced.

EFFLUENT SAMPLING

The velocity of flow was calculated from the flow rate and the net inside area of the 12in (300 mm) nominal size cement-lined pipe.

The sampling flow rate depended on the pressure produced by the raw water pumps at different speeds and was established by recording the time required for the collection of the sample.

SECTION 6

LABORATORY ANALYSIS

LABORATORY

The analyses of the specimens were carried out in the Hydraulics Laboratory of the Public Works Department of New South Wales at Manly Vale.

TESTS

Limitations of the Laboratory Analysis

The equipment used requires a mass of at least 3 grams solids between 0.088 and 1.68 mm sizes to be present in the sample. The frequency distribution analysis of the particle sizes for those samples which had less solids than 3 grams could not be carried out.

Organic-Inorganic Matter

Attempt was made to separate the inorganic matter from the organic particles by burning in an oven. This test was carried out on six independent samples and resulted in indicating negligible quantities of organic matter only.

Particle Size Distribution

The solids content of the sample delivered to the laboratory was allowed to resettle in the original drum liner polyehtylene bag. After a minimum of two days the supernatant water was drained off leaving about lin (25 mm) of water above the settled material, the solids were dried in oven and the dry mass of the total solids was established with an electronic analytical balance.

The fines smaller than 0.088 mm were removed by sieving and washing and the particles larger than 1.68 mm were removed by sieving. The masses of both the fine and coarse fractions thus removed were weighed. The fraction between 0.088 and 1.68 mm was analysed in a settling column attached to a Hewlett Packard 21 MX Data Logger and the frequency of the particle size distribution was printed out both numerically and in the form of frequency distribution and integration curves.

RESULTS

The curves plotted by the Data Logger for samples yielding significant

results and the concentrations of solids calculated from the total volume of samples and the masses of solids in the samples are shown in Figures 15 to 54 inclusive.

SECTION 7

EFFICIENCY OF SOLIDS REMOVAL

ERRORS DUE TO THE INFLUENT SAMPLING PROCEDURE

Comprehensive and wide ranging studies published in Ref. 3 and Ref. 4 established that the concentration of solids in the sample collected is dependent on:

the shape and construction of the intake ports

the direction of the intake ports

the velocity of sampling related to the main stream velocity

the size and density (specific gravity) of solids collected

the position of the sampler in the vertical cross-section of the conduit

the solids transport conditions in the rectangular conduit.

Shape of the Intake Ports

The construction of the intake ports has a comparatively minor effect on the retrieval efficiency (Fig. 22, Ref. 4) and it is assumed that the pipe socket used in this instance was equivalent to the standard nozzle (Fig. 9, Ref. 4).

Direction of Ports

The ports were constructed to face the main flow and thus no correction of the solids content of the sample was required for this reason.

Sampling Velocity and Size of Solids

There were significant variations in the ratio of the sampling velocity and the main stream velocity. The laboratory results of the solids content of the sample therefore had to be modified.

Figures 10 to 14 inclusive (Ref. 4) showing the sampling error caused by the velocity ratio have been synthesized by regression analysis:

$$E = \ln a\,(10V)^{b} - 100 \qquad \text{(Eqn 1)}$$

where E = sampling error (%)

$a = 0.5022\,(d-0.125)^{0.333} + 4.88)$ regression

$b = 0.5679\,(d-0.1)^{0.333} - 0.29\,)$ coefficients

V = ratio of sampling to main stream velocity

d = diameter of particles (m)

In each sample the mass of each particle size group was calculated in accordance with the frequency distribution supplied by the laboratory analysis and then corrected for this sampling error by application of Eqn 1. The corrected masses were summed and the resulting corrected concentrations of solids were used in the further calculations.

Solids Transport Conditions in the Rectangular Conduit

Inspections after Runs 18 and 34 disclosed that a considerable settlement of solids had taken place in the intake conduit between the point of adding sand and the swirl degritter. Because of the long period which elapsed between subsequent inspections it was uncertain when and at what rate the solids settled in the conduit and, therefore, the efficiency of the swirl degritter could not be calculated directly from the relationship between the concentration of sand added and the concentration of solids in the effluent samples.

For the flow conditions encountered there is no relevant information available in literature on the solids transport rate and the vertical distribution characteristics of solids. It was decided that another set of tests be carried out where frequent inspections verify that all the solids introduced into the system actually reach the swirl degritter and ensure that the average concentration of solids in the conduit is uniform and therefore the influent samplers at Points 3 and 4 sample the local concentrations related to these known average concentrations of solids introduced into the flow.

Runs 36 to 55 were thus used to establish the solids transport characteristics of the influent conduit. The ratios of the sampled concentrations of solids to the average concentrations of solids were plotted against the ratios of the sampling velocity to the main stream velocity in order to verify that the data yielded significant relationships. Curves were fitted through regression analysis. The plotting of the data with the corresponding regression curves and explanation of the notation used are shown in Figures 8 to 11 inclusive.

This analysis proved that significant correlation existed between the efficiency of the samplers (ratio of sampled to artificially added concentrations of solids) and the main stream (influent conduit) velocities,

$$\frac{C_s}{C_c} = 0.3326 - 0.3148 \ln\left(\frac{V_s}{V_c}\right)$$

C_c : Concentration of sand added, mg/L.
C_s : Concentration of solids in sample, mg/L.
V_s : Sampling velocity, m/s.
V_c : Velocity in conduit, m/s.
40: Run number

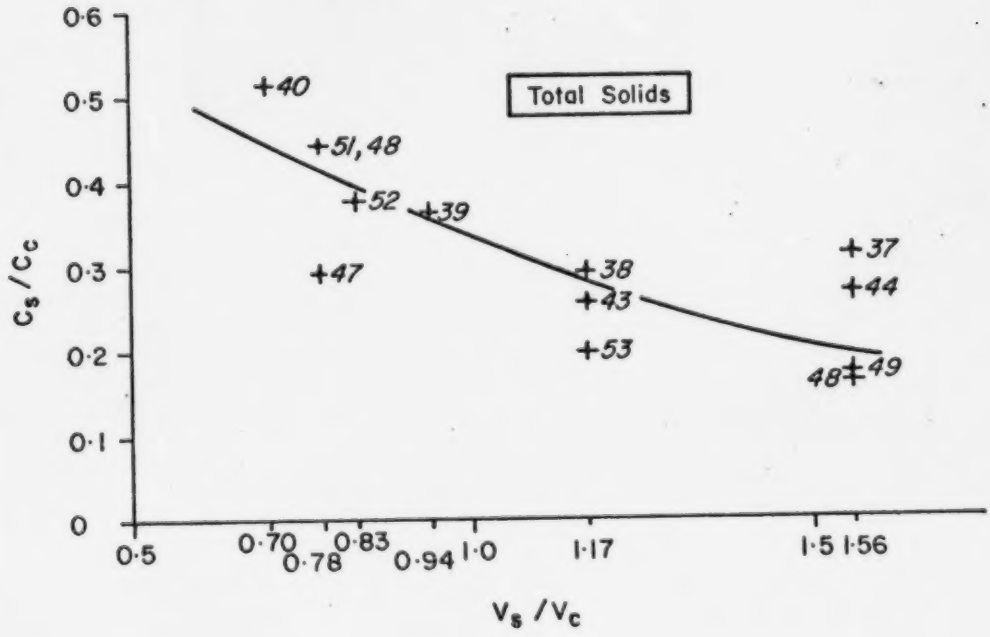
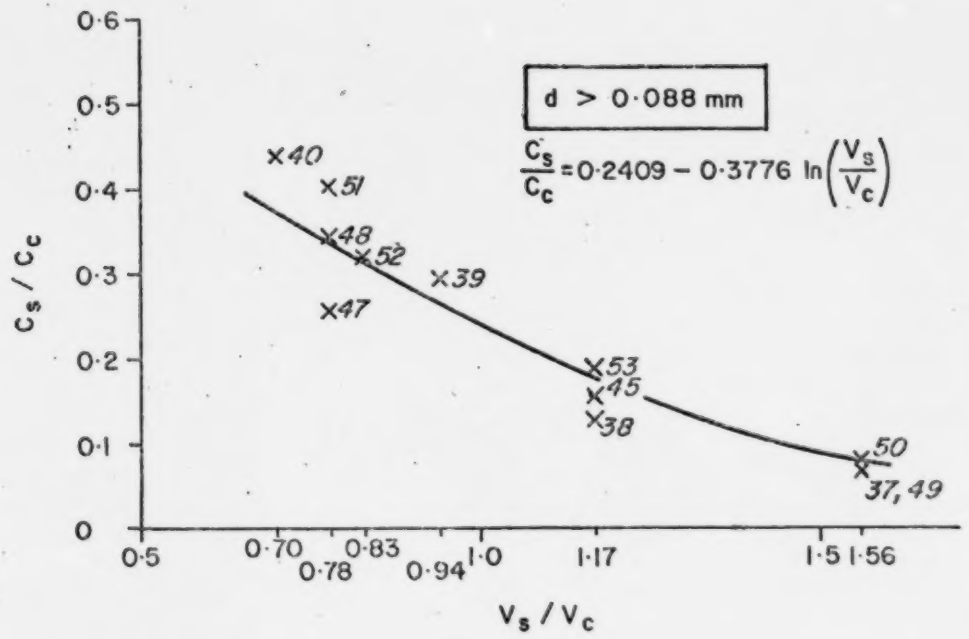


FIGURE 8. $\frac{C_s}{C_c}$ — $\frac{V_s}{V_c}$ CURVE RUNS 36 - 55 (POINT 3)



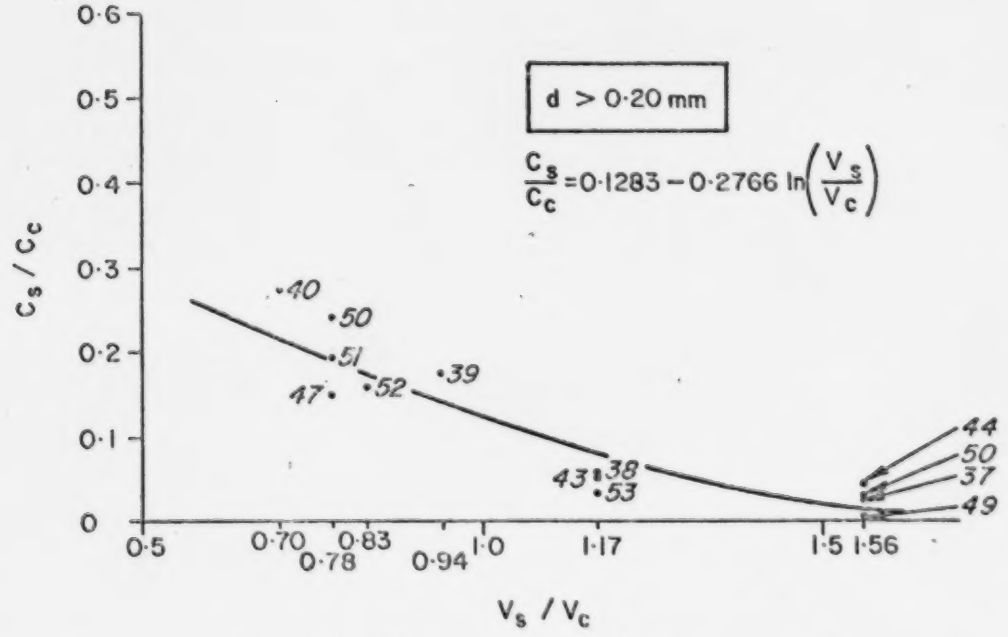


FIGURE 9. $\frac{C_s}{C_c}$ —— $\frac{V_s}{V_c}$ CURVES RUNS 36 – 55 (POINT 3)

$$\frac{C_s}{C_c} = 0.1512 - 0.1318 \ln\left(\frac{V_s}{V_c}\right)$$

C_c: Concentration of sand added, mg/L.
C_s: Concentration of solids in sample, mg/L.
V_s: Sampling velocity, m/s.
V_c: Velocity in conduit, m/s.
40: Run Number

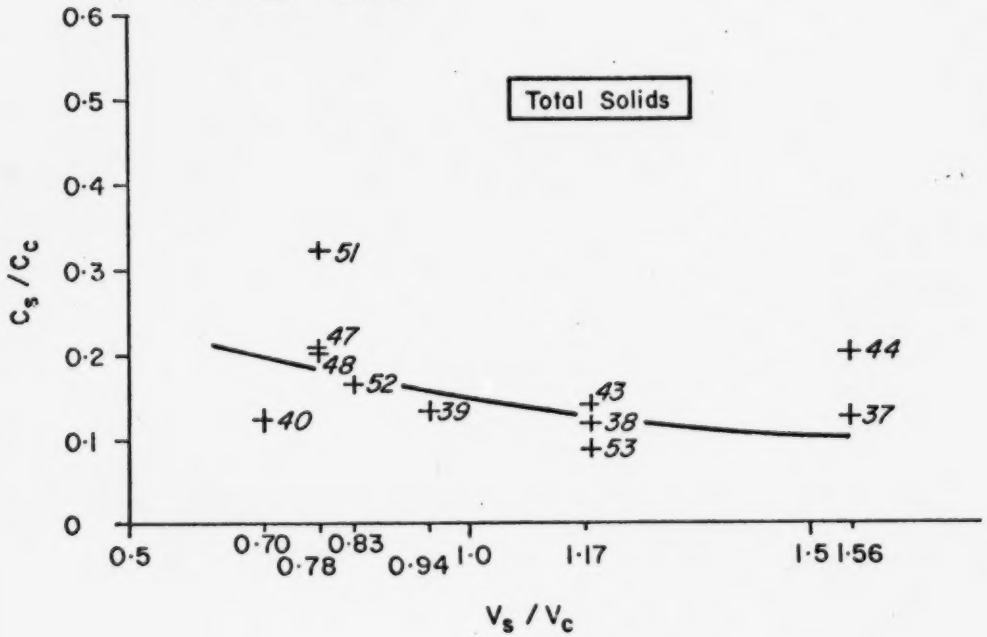
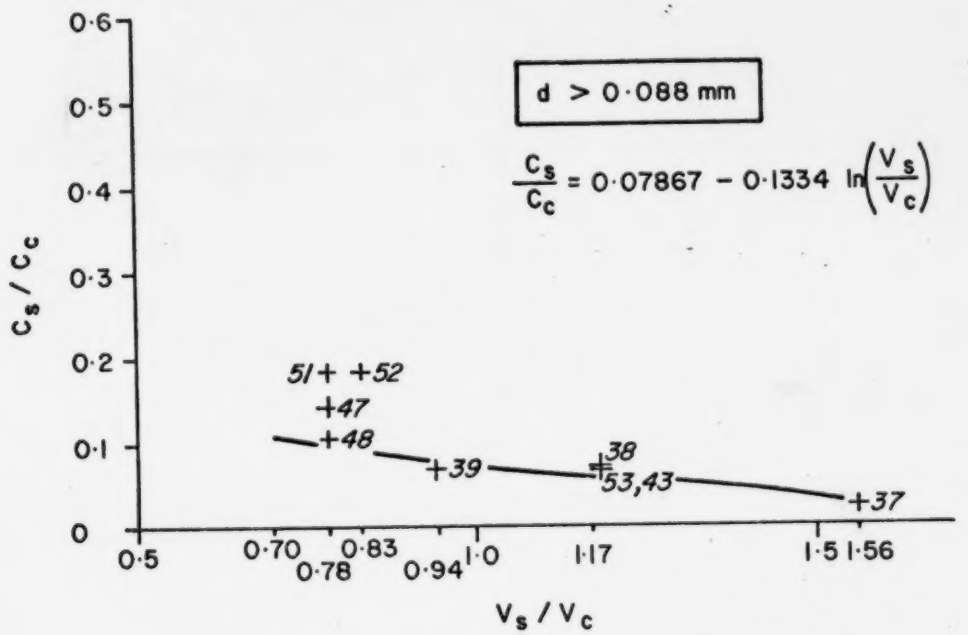


FIGURE 10. $\frac{C_s}{C_c}$ —— $\frac{V_s}{V_c}$ CURVE RUNS 36 – 55 (POINT 4)



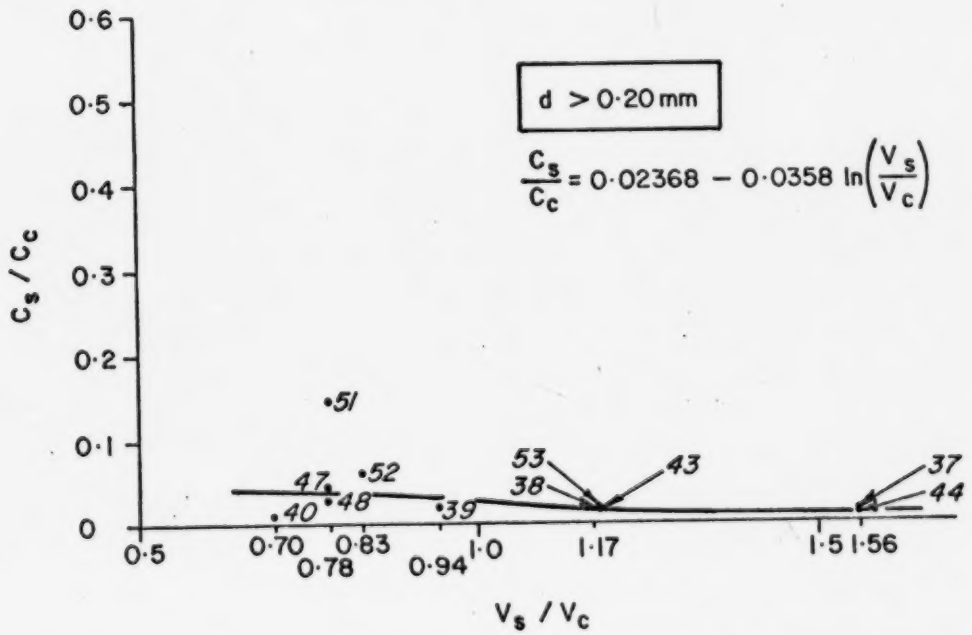


FIGURE 11. $\frac{C_s}{C_c}$ —— $\frac{V_s}{V_c}$ CURVES RUNS 36 – 55 (POINT 4)

with some samples inevitably showing freak information.

After eliminating the runs which were obviously inconsistent due to some freak condition in the conduit, or due to some mishaps during sampling, handling or testing of samples, the relationships between the sampled and average concentration of solids in the influent were established for samples withdrawn at points 3 and 4. The multiple regression analyses correlating the average velocity in the intake conduit on the one hand and the ratios of the concentrations of the three groups of solids in the samples from the centre of the conduit (Point 3) and the top of the conduit (Point 4) to the average concentration in the conduit on the other hand resulted in the following expressions :

Total solids : $$(e^{V})^2 = a + b \frac{C_{3(T)}}{C_{a(T)}} + c \frac{C_{4(T)}}{C_{a(T)}} \pm E_{(T)}$$ Eqn. 2

with a = - 11.9320

b = + 97.5511

c = - 11.7306

$E_{(T)}$ = 0.3933

Solids larger than d = 0.088 mm

$$(e^{V})^2 = a + b \frac{C_{3(0.088)}}{C_{a(0.088)}} + c \frac{C_{4(0.088)}}{C_{a(0.088)}} \pm E_{(0.088)}$$ Eqn. 3

with a = -3.4928

b = 92.7066

c = -13.0351

$E_{(0.088)}$ = 0.3540

Solids larger than d = 0.2 mm

$$e^{V^2} = a + b \frac{C_{3(0.2)}}{C_{a(0.2)}} + c \frac{C_{4(0.2)}}{C_{a(0.2)}} \pm E_{(0.2)}$$ Eqn. 4

with a = 0.9162

b = 55.6222

c = 35.7718

$E_{(0.2)}$ = 0.2149

where e = base of natural logarithm

V = average velocity of influent in conduit in m/s

a, b, c, = regression coefficients

$C_{3(T)}$, $C_{3(0.088)}$, $C_{3(0.2)}$ = concentration of solids in the sample for the particle size groups at sampling point 3 (mg/L)

$C_{4(T)}$, $C_{4(0.088)}$, $C_{4(0.2)}$ = concentration of solids in the sample for the particle size groups at sampling point 4 (mg/L)

$C_{a(T)}$, $C_{a(0.088)}$, $C_{a(0.2)}$ = concentration of solids for the particle size groups in the added sand (accepted as the average concentration in the conduit for the purposes of the regression analyses) (mg/L)

$E_{(T)}$, $E_{(0.088)}$, $E_{(0.2)}$ = Standard errors of estimate for 99 per cent probability in the f(V) quantity on the left hand side of the Equations 2, 3 and 4.

Equations 2, 3, and 4 were rewritten in the form

$$C_{av(T)} = \frac{bC_{3(T)} + cC_{4(T)}}{(e^{V)2} + a \pm E_{(T)}} \qquad \text{Eqn. 5}$$

$$C_{av(0.088)} = \frac{bC_{3(0.088)} + cC_{4(0.088)}}{(e^{V)2} + a \pm E(0.088)} \qquad \text{Eqn. 6}$$

$$C_{av(0.2)} = \frac{bC_{3(0.02)} + cC_{4(0.2)}}{e^{V2} + a \pm E(0.2)} \qquad \text{Eqn. 7}$$

These equations were applied to the laboratory results for the sample solid concentrations, which had already been corrected for sampling error due to the ratio of sampling velocity to average main stream velocity in the influent conduit to calculate the average concentration of the respective size groups of solids in the influent conduit.

The summary of the calculation results is shown in Tables 3 and 4.

ERRORS DUE TO THE EFFLUENT SAMPLING PROCEDURE

Solids Distribution at Sampling Point 5

The effluent was sampled at 4ft (1.2 m) downstream from the delivery side of the main operating pump and within the zone of high turbulence. Therefore, it can be safely assumed that the water at the point of sampling contained the average concentrations.

Efficiency of Sampling

Because of the high velicity of the main flow and construction considerations, it was impossible to achieve a sampling velocity similar to the main velocity. However, the lower sampling velocity is consistent with a sample having a concentration higher than the true concentration and thus the adoption of the sample concentration results in a lower removal efficiency rate and means erring on the safe side. The fact that the effluent sampler was bent by the pressure of the water during sampling (and reduced the effective area of the intake slot) does not materially alter the above argument, because the resulting increase in the intake velocity was insignificant compared with the main stream velocity in the pipe.

Therefore, it can safely be assumed that the concentration of solids in the samples was higher than or at least the equivalent of the concentration of solids in the effluent.

REMOVAL EFFICIENCY OF SOLIDS

The removal efficiency of solids were calculated with Equation 8.

$$R\% = \left(1 - \frac{C_5}{C_{av}}\right) \times 100 \qquad \text{Eqn. 8}$$

where C_5 = the concentration of solids at Point 5 in the sample (mg/L)

C_{av} = The average concentrations of the groups of solids in the influent conduit, obtained from Equations 5 to 7 respectively (mg/L)

Effect of the Standard Errors in the Regression Analysis

The general shape of the Equations 5 to 7 is

$$C_{av} = \frac{bC_3 + cC_4}{f(V) + a \pm E} \qquad \text{Eqn. 9}$$

If this expression is substituted into Equation 8 it becomes:

$$R\% = \left(1 - \frac{C_5}{bC_3 - cC_4} \times (f(V) + a) \mp \frac{C_5}{bC_3 + cC_4} E\right) \times 100 \qquad \text{Eqn. 10}$$

The third member inside the brackets represents the error of the regression analysis for 99% probability. The actual quantity of this expression had been calculated for each case. It was found that it generally did not exceed $\pm 0.4\%$ and so it was ignored in the representation.

Representation of Results

The removal efficiencies are shown in Tables 5 and 6 and also in Figures 12, 13 and 14.

TABLE 3 SUMMARY OF RUNS 36-55

RUN NUMBER	FLOW RATE	CONCENTRATION OF SAND INTRODUCED	INFLUENT VELOCITY	SAMPLING / INFLUENT VELOCITY	INFLUENT CONCENTRATION POINT 3 SAMPLE ** TOTAL SOLIDS	INFLUENT CONCENTRATION POINT 3 SAMPLE ** PARTICLES > 0·088mm	INFLUENT CONCENTRATION POINT 3 SAMPLE ** PARTICLES > 0·2 mm	INFLUENT CONCENTRATION POINT 4 SAMPLE ** TOTAL SOLIDS	INFLUENT CONCENTRATION POINT 4 SAMPLE ** PARTICLES > 0·088mm	INFLUENT CONCENTRATION POINT 4 SAMPLE ** PARTICLES > 0·2 mm	AVERAGE IN CONDUIT TOTAL SOLIDS	AVERAGE IN CONDUIT PARTICLES > 0·088mm	AVERAGE IN CONDUIT PARTICLES > 0·2 mm	EFFLUENT CONCENTRATION POINT 5 TOTAL SOLIDS	EFFLUENT CONCENTRATION POINT 5 PARTICLES > 0·088 mm	EFFLUENT CONCENTRATION POINT 5 PARTICLES > 0·2 mm	EFFICIENCIES TOTAL SOLIDS	EFFICIENCIES PARTICLES > 0·088 mm	EFFICIENCIES PARTICLES > 0·2 mm
—	L/s	mg/L	m/s	—	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%	%	%
36	450	—	0·83	1·56	8·6	—	—	11·6	—	—	—	—	—	17·0	5·0	—	—	—	—
37	450	774	0·83	1·56	243·4	43·6	11·7	97·5	13·5	7·3	—	—	—	86·3	26·2	5·4	—	—	—
38	600	600	1·11	1·17	173·7	98·5	23·0	74·9	31·7	5·8	760	686	215	94·5	46·4	7·36	87·6	93·2	93·1
39	750	720	1·39	0·94	260·8	183·8	84·3	93·9	42·3	10·9	869	841	489	149·5	85·4	19·0	82·8	89·8	96·1
40	1000	675	1·86	0·70	347·7	255·7	124·1	83·0	33·1	5·4	619	520	201	194·3	132·3	50·3	68·6	74·6	75·0
41	300	—	0·56	2·33	1·4	0·3	—	1·1	—	—	9	—	—	4·1	—	—	—	—	—
42	150	—	0·28	4·68	1·7	—	—	1·5	—	—	12·4	—	—	1·0	—	—	—	—	—
43	600	643	1·11	1·17	163·2	87·7	15·4	89·4	31·3	4·6	704	609	148	154·3	58·3	5·4	78·0	90·4	96·3
44	450	1143	0·83	1·56	310·0	138·7	32·5	231·2	73·6	7·2	1601	1360	377	113·9	47·1	11·9	92·9	96·5	96·8
45	150	—	0·28	4·68	0·9	0·1	—	1·6	0·2	—	—	—	—	1·0	0·2	—	—	—	—
46	300	—	1·67	0·78	1·3	0·1	—	1·5	0·2	—	—	—	—	19·9	18·2	5·2	—	—	—
47	900	267	1·67	0·78	79·8	59·8	27·0	55·4	32·2	7·7	176	162	90	49·0	27·6	14·13	72·0	82·9	84·9
48	900	348	1·67	0·78	153·7	120·3	56·3	69·5	31·3	7·0	353	339	171	88·5	56·0	20·5	74·9	83·5	88·0
49	450	640	0·83	1·56	110·5	38·1	2·8	69·0	7·5	—	580	392	28	63·8	32·0	6·9	89·0	91·8	75·7
50	450	348	0·83	1·56	56·4	23·8	6·3	38·0	5·1	—	394	245	63	41·4	13·1	4·2	89·5	94·6	93·4
51	900	642	1·67	0·78	371·8	252·9	114·2	269·0	190·0	83·4	825	661	473	204·5	137·7	50·0	75·2	79·2	89·4
52	850	892	1·58	0·83	334·6	244·3	94·8	196·8	138·0	36·8	854	770	422	159·7	96·7	24·5	81·3	87·4	94·2
53	600	1263	1·11	1·17	247·8	140·4	28·4	106·1	75·9	14·8	1085	947	305	136·7	49·8	6·2	87·4	94·7	98·0
54	600	—	1·11	1·17	1·4	0·6	—	1·3	0·4	—	—	—	—	14·5	12·3	4·3	—	—	—
55	600	—	1·11	1·17	1·6	0·3	—	1·0	0·1	—	—	—	—	5·3	3·8	—	—	—	—

* Laboratory results for sampling errors due to $\frac{\text{sampling}}{\text{main stream}}$ velocity ratio

** Calculated from regression analysis *** insufficient solids in samples

TABLE 4 SUMMARY OF RUNS 1-34

RUN NUMBER	FLOW RATE	CONCENTRATION OF SAND INTRODUCED	INFLUENT VELOCITY	INFLUENT CONCENTRATION									EFFLUENT CONCENTRATION POINT 5			EFFICIENCIES		
				POINT 3 *			POINT 4 *			AVERAGE IN CONDUIT **								
				TOTAL SOLIDS	PARTICLES > 0·088mm	PARTICLES > 0·2 mm	TOTAL SOLIDS	PARTICLES > 0·088 mm	PARTICLES > 0·2 mm	TOTAL SOLIDS	PARTICLES > 0·088mm	PARTICLES > 0·2 mm	TOTAL SOLIDS	PARTICLES > 0·088mm	PARTICLES > 0·2 mm	TOTAL SOLIDS	PARTICLES > 0·088 mm	PARTICLES > 0·2 mm
—	L/s	mg/L	m/s	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%	%	%
7	605	440	1·05	113·3	25·5	1·0	191·7	20·3	1·5	438	180	17	112·1	7·7	—	74·4	95·7	100
8	605	440	1·05	96·6	28·8	2·4	109·8	13·2	0·7	405	214	24	121·8	8·0	—	69·9	96·3	100
9 B	300	1777	0·52	210·4	43·9	2·0	213·7	26·8	1·0	1223	588	9	126·1	7·1	—	89·7	98·8	100
10	440	1211	0·76	356·7	162·3	20·8	287·7	63·9	2·5	1903	1767	158	226·2	39·6	2·0	88·1	97·8	98·7
20	950	798	1·64	336·6	228·8	94·6	101·5	31·7	4·1	822	692	298	185·1	44·0	28·5	77·5	93·8	90·4
21	950	494	1·64	203·4	140·9	52·0	104·1	37·9	3·3	484	420	165	126·1	68·9	24·4	73·9	83·8	85·2
22	950	361	1·64	165·4	120·0	50·2	65·9	15·1	1·5	399	363	156	85·9	38·3	8·3	78·5	89·5	94·6
23	950	165	1·64	99·3	68·0	26·4	35·8	8·0	—	241	206	81	50·0	23·4	5·4	79·2	88·6	93·3
26	680	265	1·18	42·0	21·0	5·4	30·4	7·3	—	166	131	40	28·8	7·9	—	82·3	94·0	***
27	680	460	1·18	75·1	41·6	10·0	63·1	17·0	2·2	292	258	27	52·4	16·2	1·5	83·0	93·2	94·3
29	680	921	1·18	282·0	149·1	28·1	116·8	21·4	1·8	1031	962	216	156·2	42·9	2·2	84·8	95·5	98·9
30	430	1674	0·74	256·2	72·8	7·5	99·6	6·3	—	1459	845	80	143·3	15·1	3·6	90·1	98·2	95·5
31	430	1196	0·74	147·2	51·5	3·6	74·8	10·0	—	826	589	38	89·5	15·1	0·4	89·2	97·4	98·9
32	430	930	0·74	151·5	55·1	5·8	116·1	19·0	1·5	872	616	72	81·7	14·8	0·3	90·0	97·6	99·6
33	430	364	0·74	75·2	28·7	3·8	42·2	7·2	—	419	326	40	42·5	10·0	—	89·6	96·6	***
34	430	—	0·74	20·9	7·5	—	8·4	4·2	—	119	81	—	9·5	4·5	—	92·0	94·5	***

* Laboratory results for sampling errors due to $\frac{\text{sampling}}{\text{main stream}}$ velocity ratio

** Calculated from regression analysis *** Insufficient solids in samples

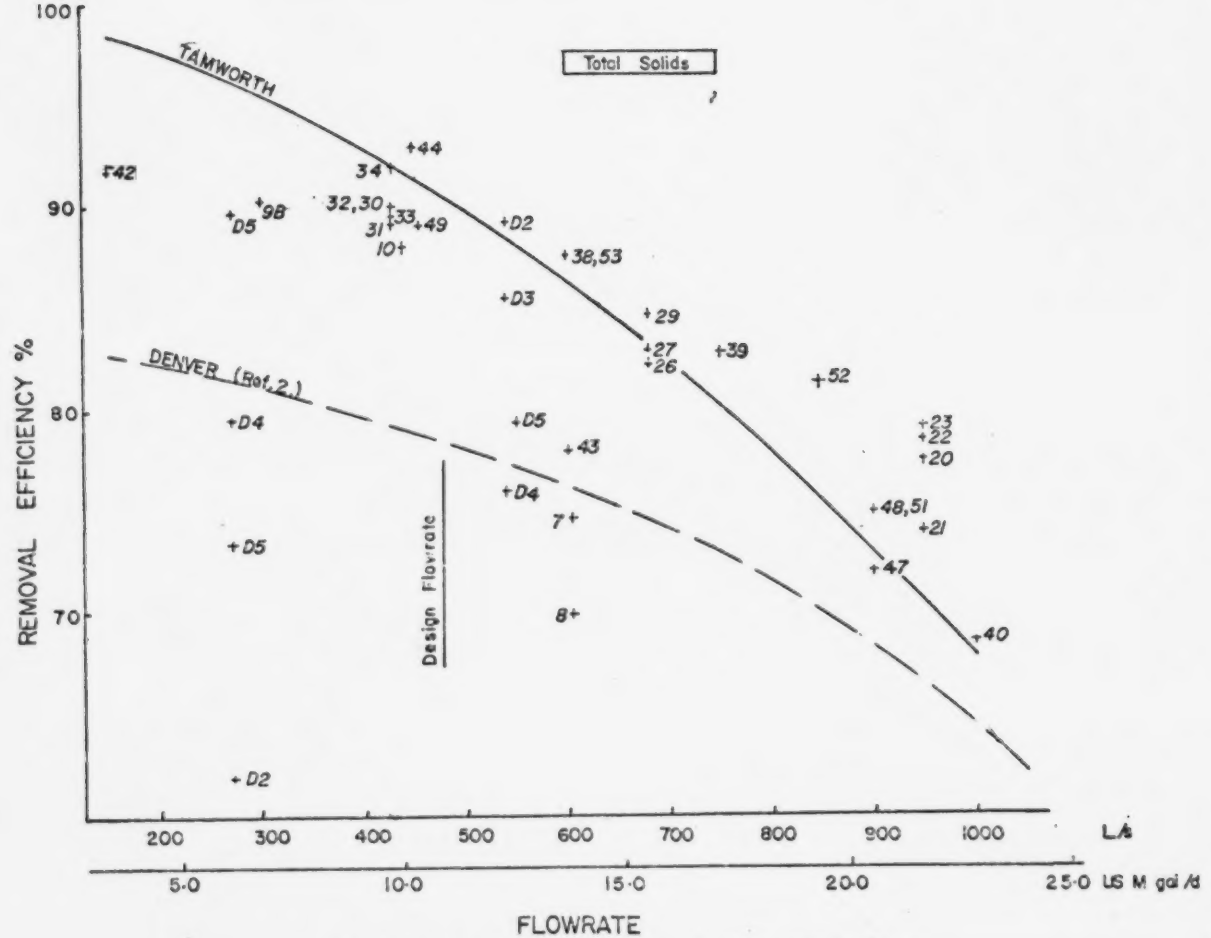


FIGURE 12 REMOVAL EFFECIENCIES

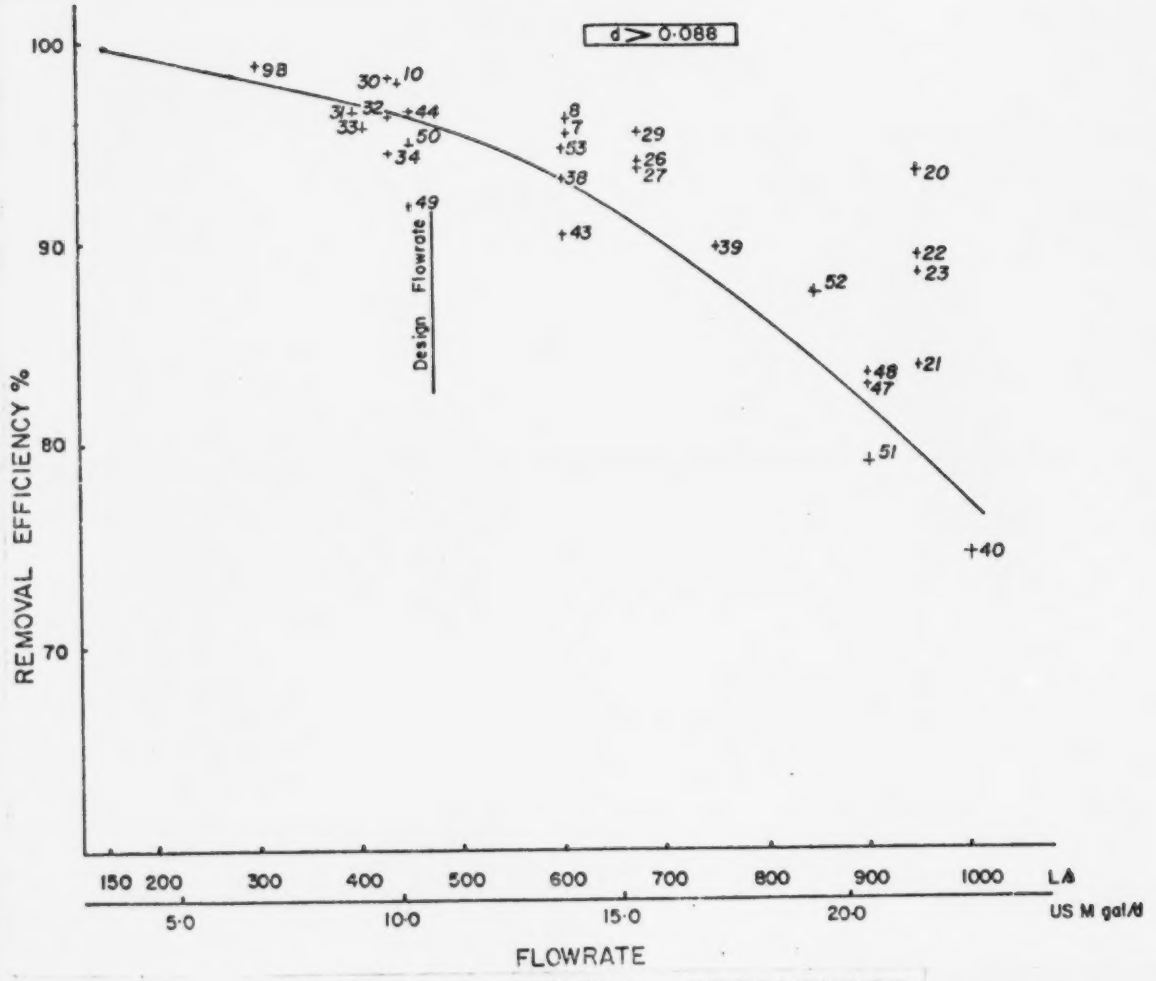


FIGURE 13 REMOVAL EFFECIENCIES

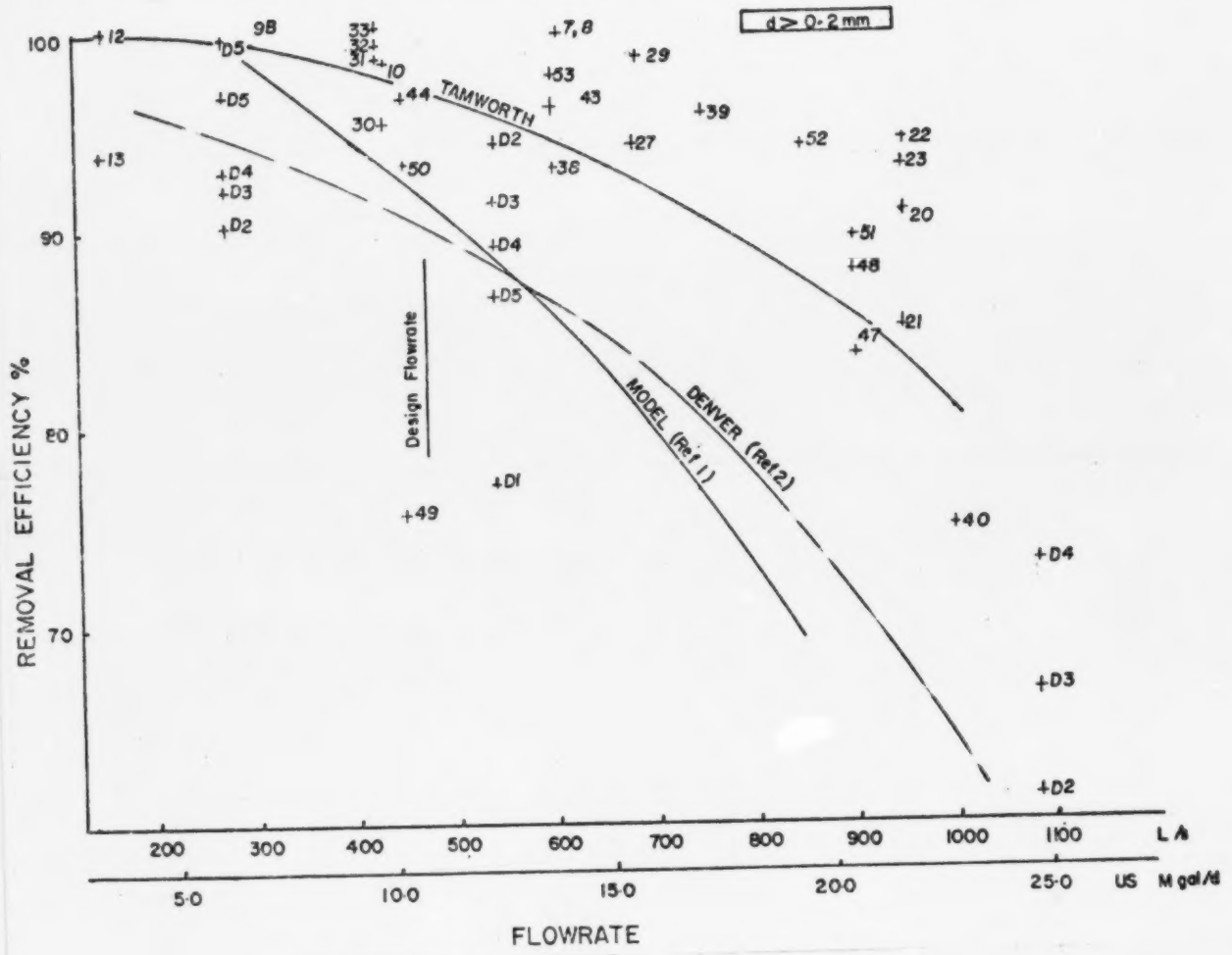


FIGURE 14 REMOVAL EFFECIENCIES

SECTION 8

COST ANALYSIS

Cost Basis

The costs are based on the actual construction cost of the swirl grit separator.

The estimated cost of an equivalent longitudinal constant velocity grit chamber assumed to be constructed on the same site with the swirl contract unit rates.

Unit Rates

Excavation, backfilling, including dewatering	$A 25/$m^3$
Reinforced concrete including formwork	$A500/$m^3$
Contingencies, investigations, design and construction supervision costs	30%

Assumptions

a. Both the swirl grit separator and the longitudinal constant velocity grit chamber have been dimensioned for 7540 US gpm (470L/s) flow, to be constructed in the flood plains of the Peel River, for gravitational flow between the intake and the pumping station.

b. Equipment for the swirl grit separator includes all steel works within the chamber and a hydraulic grit eductor.

c. Equipment for the constant velocity grit chamber include two screw conveyors and hydraulic grit eductors.

TABLE 5. CONSTRUCTION COST OF SWIRL GRIT SEPARATOR

Description	Quantity	Amount $A
Excavation including backfilling and dewatering during construction	1520 cu m (2000 cu yd)	38 000
Reinforced concrete including formwork	170 cu m (220 cu yd)	85 000
Miscellaneous equipment (spoilers, weir, pipework, eductor, access)	Item	57 000
	Total	180 000

TABLE 6. CONSTRUCTION COST OF CONSTANT VELOCITY GRIT CHAMBER

Description	Quantity	Amount $A
Excavation including backfilling and dewatering during construction	6000 cu m (7850 cu yd)	150 000
Reinforced concrete including formwork	350 cu m (450 cu yd)	175 000
Miscellaneous equipment (conveyors, pipework, eductors, access)	Item	100 000
	Total	425 000

COMPARISON WITH MODEL PREDICTIONS

The curves for the 16.4ft (5 m) diameter chamber were interpolated in Figures 49 and 50 of Ref. 1, the removal efficiency rates corresponding to flowrates were read, and averaged.

The resulting points were plotted in Figure 14 (d 0.2mm)

COMPARISON WITH THE DENVER PROTOTYPE RESULTS

The results obtained at Denver (Ref 2) for the grit ash are comparable with the data presented for the Tamworth structure.

The data contained in Tables A4 to A6 inclusive (Ref 2) had been recalculated based on the concentration of grit ash shown in Tables 8 to 10 inclusive (Ref 2).

The information was then tabulated in Tables 7, 8, and 9 in this Report. In order to allow comparisons between the two sets of results, the flow rates were sealed up with the scale factor of $\lambda^{2.5}$ where $\lambda=2.73$ (the ratio of the diameters of the structures). The scale up of the particle size groups based on their settling velocities did not result in a significant shift of the data and, therefore, the original distribution was adopted.

The resulting removal efficiencies were plotted in Figures 12 and 14. Values for the particle size group of d>0.088 mm could not be extracted from the available information.

REFERENCES

1. Sullivan, R.H., Cohn, M.M., Ure, J.E. and Parkinson F. The Swirl Concentrator a Grit Separator Device. EPA-670/2-74-026, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1974, pp. 82.

2. Sullivan, R.H., Ure, J.E., and Zielinski, P. EPA-600/2-77-185, Field Prototype Demonstration of the Swirl Degritter, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1977, pp. 64.

3. Shelley, P.E. Sampling of Water and Wastewater. EPA-600/4-77-039, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1977, pp. 311.

4. Federal Inter-Agency Sedimentation Project (FIASP), Laboratory Investigation of Suspended Sediment Samplers. Report No. 5. St. Paul U.S. Engineer District Sub-Office Hydraulic Laboratory, University of Iowa, Iowa City, 10, 1941, pp. 99.

5. Graf, W.H., Hydraulics of Sediment Transport. McGraw-Hill Book Company, New York, N.Y., 1971.

LEGEND

P : Sampling Point.
C_1 : Concentration of total solids.
C_2 : Concentration of solids $d \geqq 0.088$. mm
C_3 : Concentration of solids $d \geqq 0.2$ .mm
$\phi = -\log_2 d$

Conversion of Phi Values into Millimeters

phi	d mm
− 1·00	2·00
− 0·75	1·68
− 0·50	1·41
− 0·25	0·19
0	1·00
+ 0·25	0·84
+ 0·5	0·71
+ 0·75	0·60
+ 1·00	0·50
+ 1·25	0·42
+ 1·50	0·35
+ 1·75	0·30
+ 2·00	0·25
+ 2·50	0·177
+ 3·00	0·125
+ 3·50	0·088

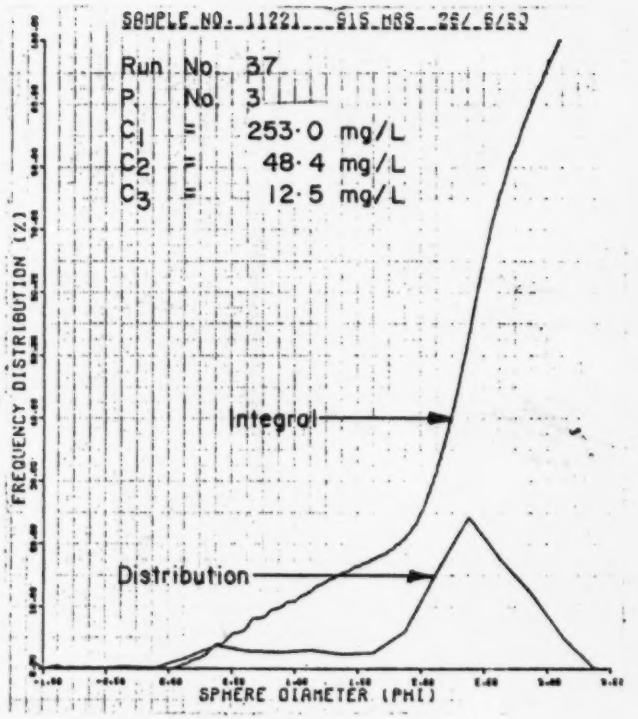
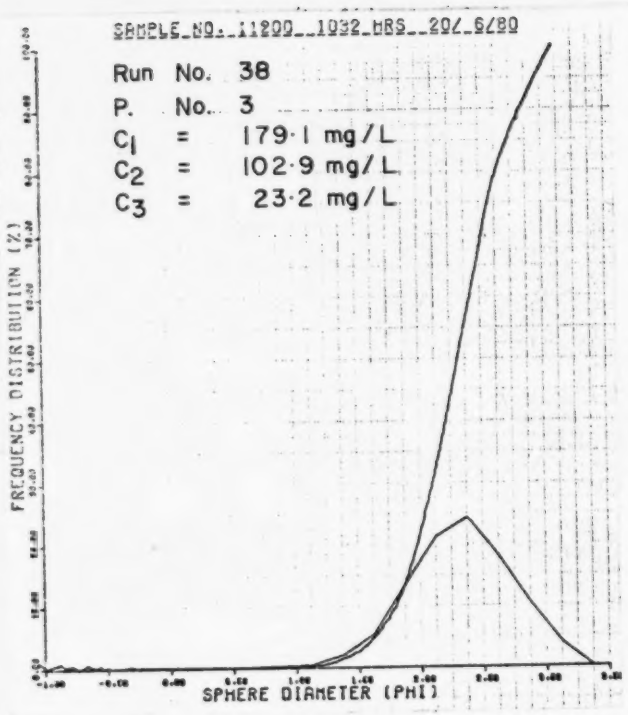


FIGURE 15 ' FREQUENCY DISTRIBUTION OF PARTICLES



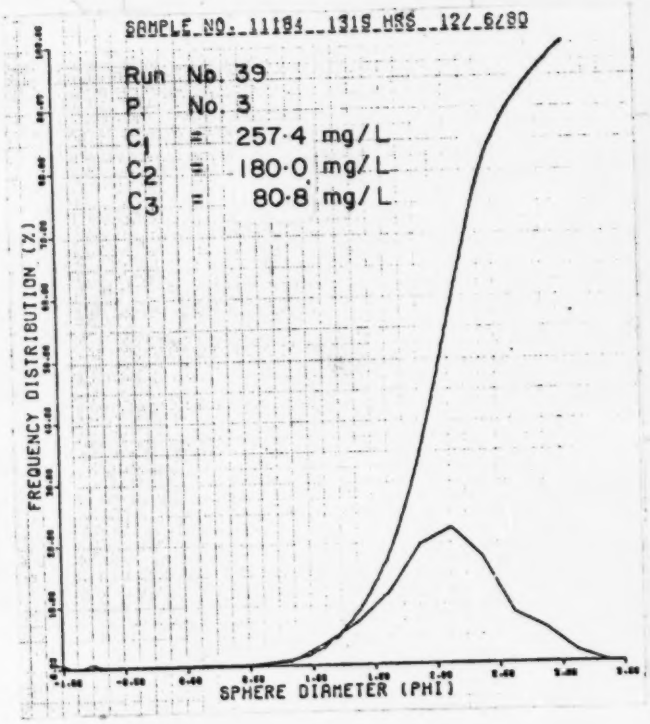
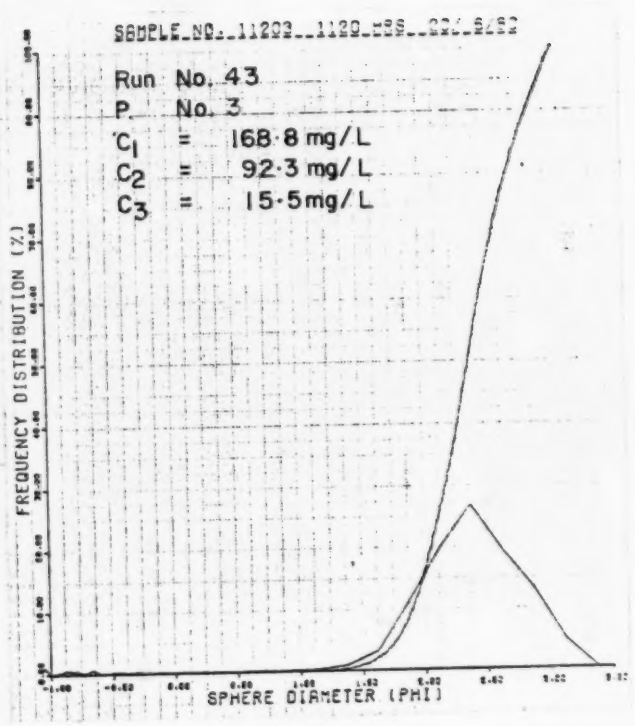


FIGURE 16 FREQUENCY DISTRIBUTION OF PARTICLES



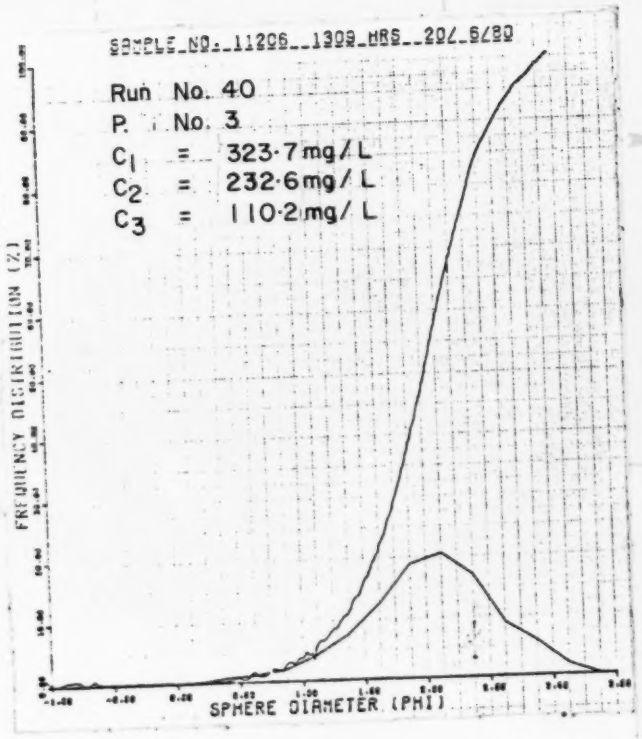
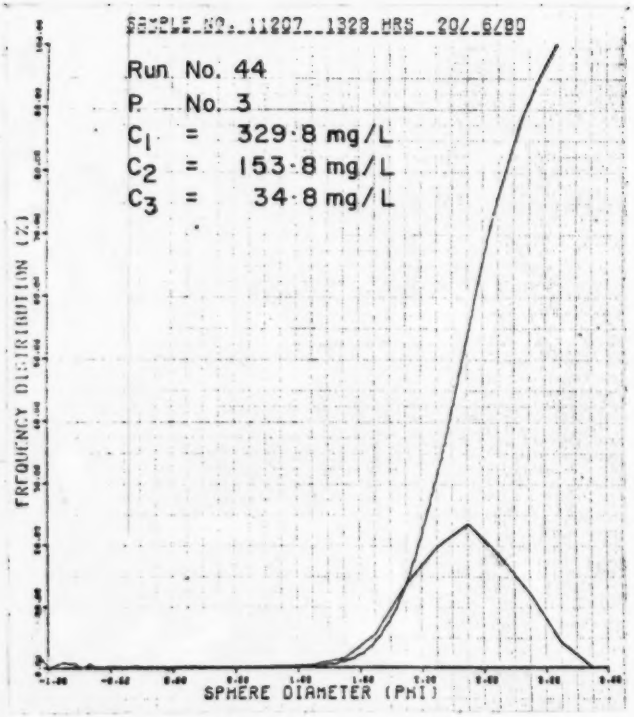


FIGURE 17 FREQUENCY DISTRIBUTION OF PARTICLES



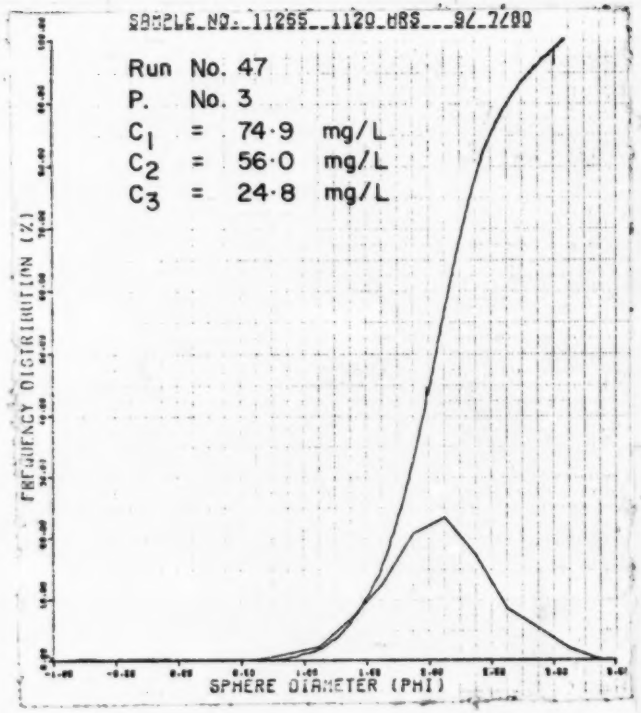
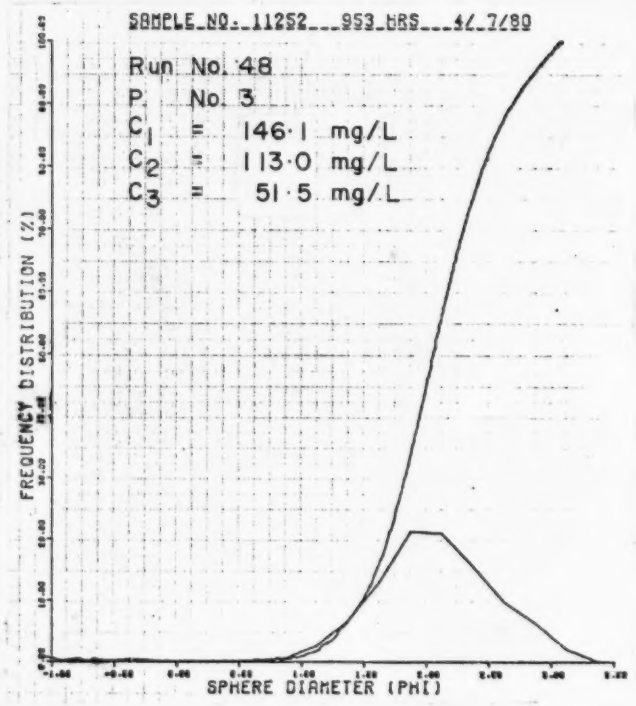


FIGURE 18 FREQUENCY DISTRIBUTION OF PARTICLES



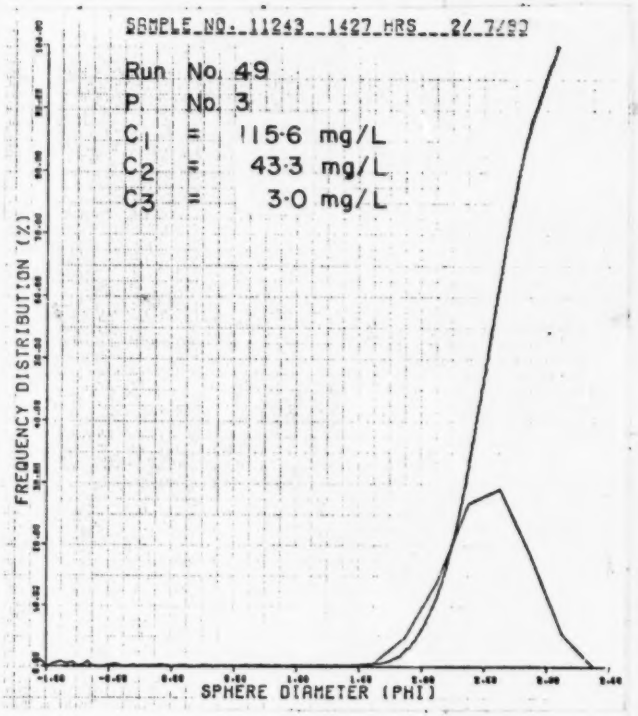
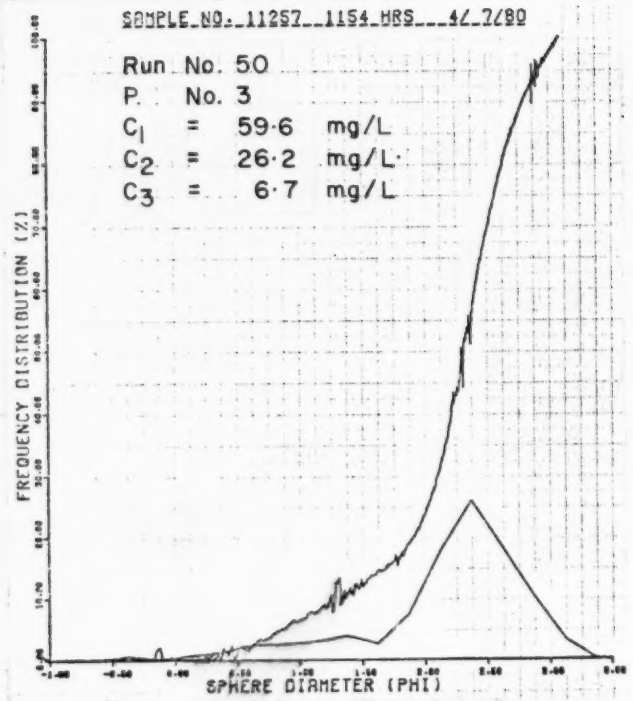


FIGURE 19 FREQUENCY DISTRIBUTION OF PARTICLES



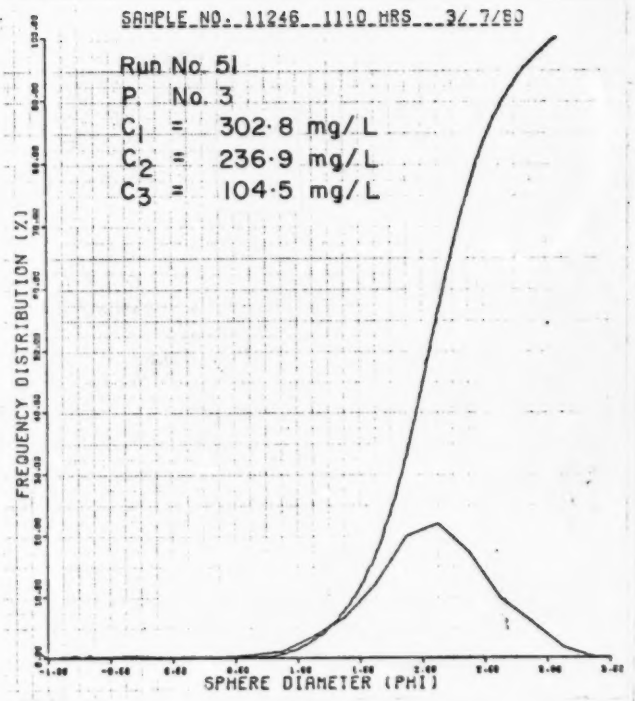
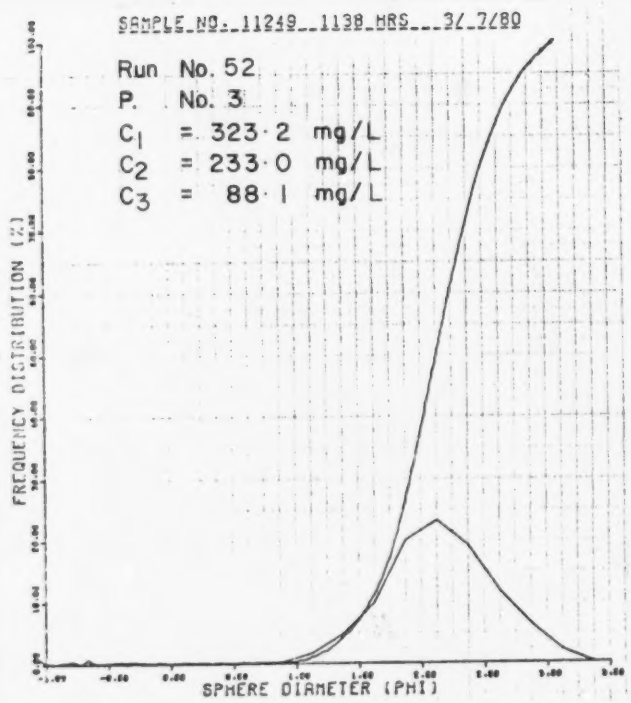


FIGURE 20 FREQUENCY DISTRIBUTION OF PARTICLES



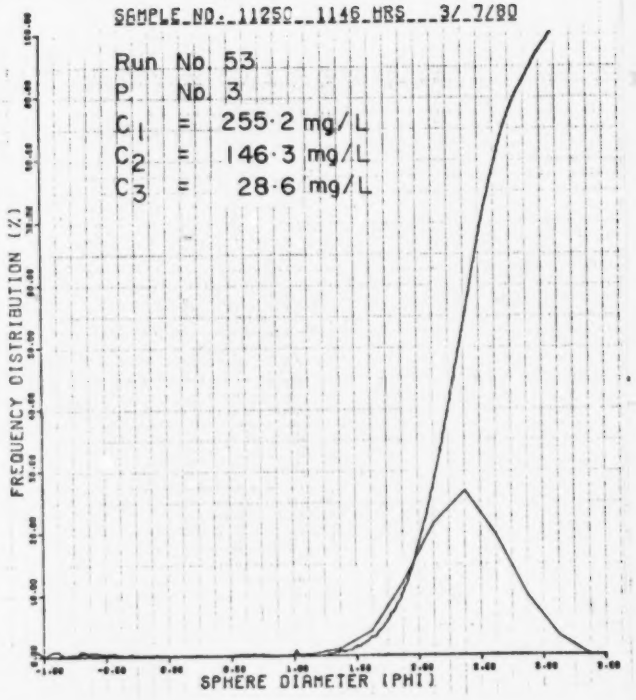


FIGURE 21 FREQUENCY DISTRIBUTION OF PARTICLES

LEGEND

P : Sampling Point.
C_1 : Concentration of total solids.
C_2 : Concentration of solids $d \geq 0{\cdot}088$. mm
C_3 : Concentration of solids $d \geq 0{\cdot}2$. mm
$\phi : -\log_2 d$

Conversion of Phi Values into Millimeters

phi	d mm
−1·00	2·00
−0·75	1·68
−0·50	1·41
−0·25	0·19
0	1·00
+0·25	0·84
+0·5	0·71
+0·75	0·60
+1·00	0·50
+1·25	0·42
+1·50	0·35
+1·75	0·30
+2·00	0·25
+2·50	0·177
+3·00	0·125
+3·50	0·088

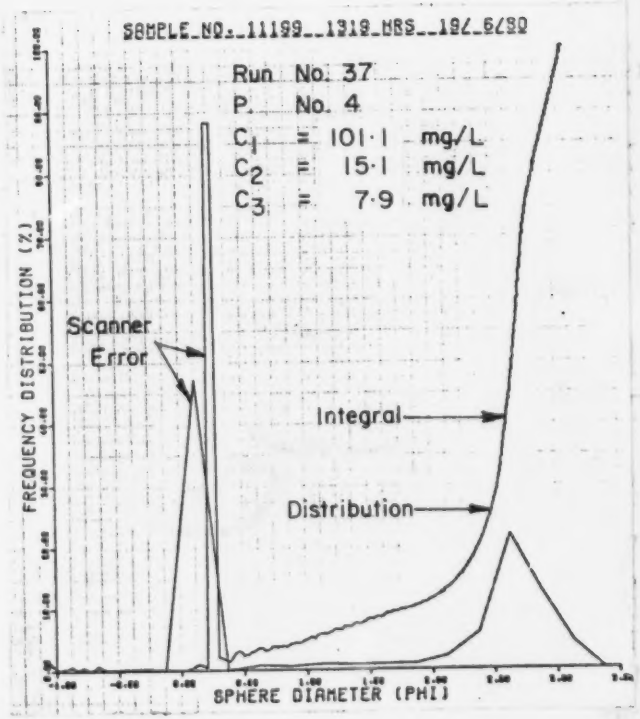
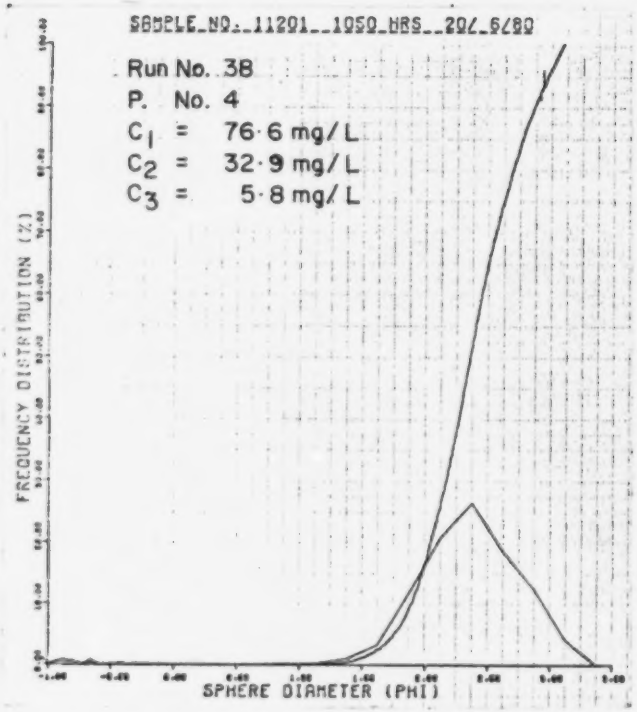


FIGURE 22 FREQUENCY DISTRIBUTION OF PARTICLES



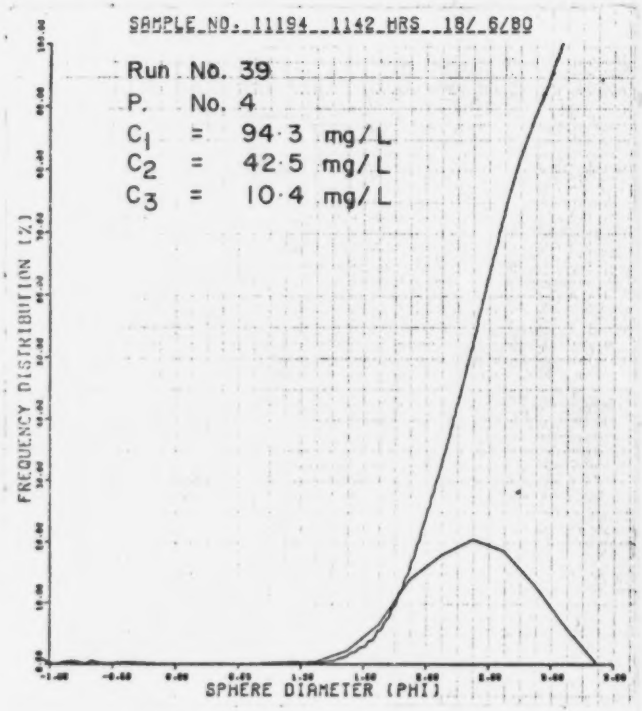
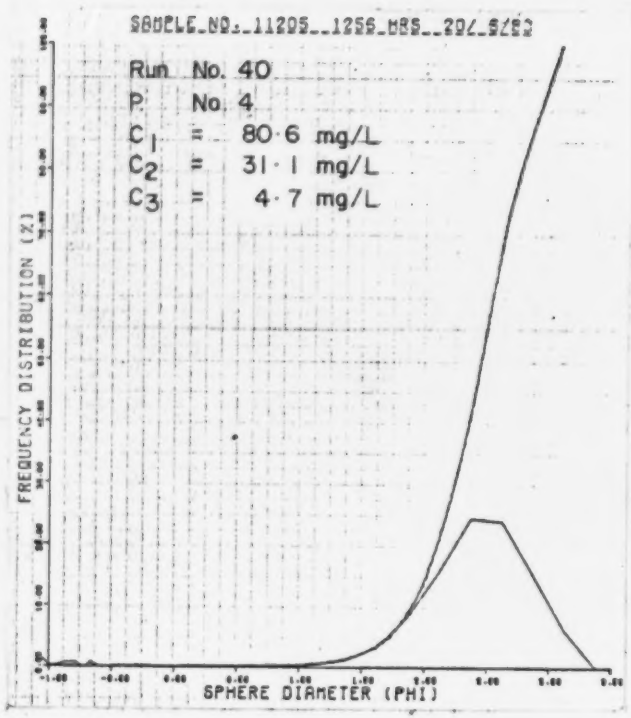


FIGURE 23 FREQUENCY DISTRIBUTION OF PARTICLES



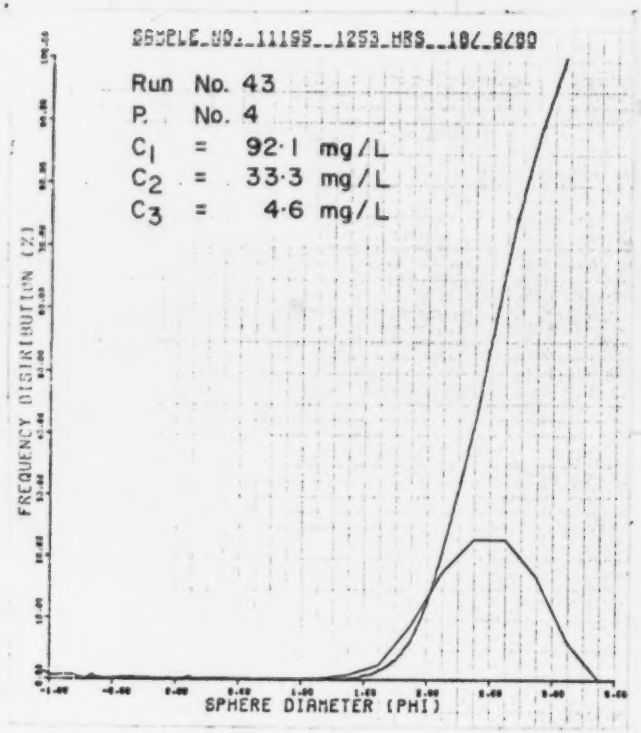
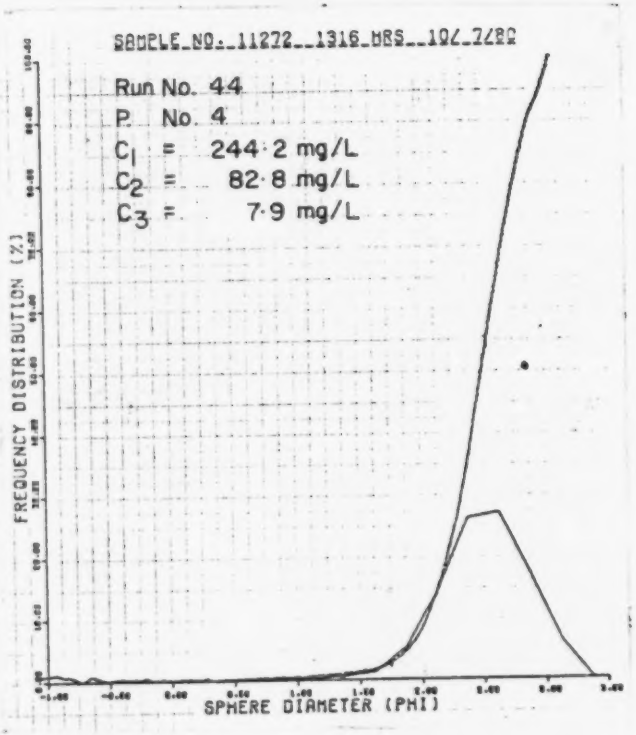


FIGURE 24 FREQUENCY DISTRIBUTION OF PARTICLES



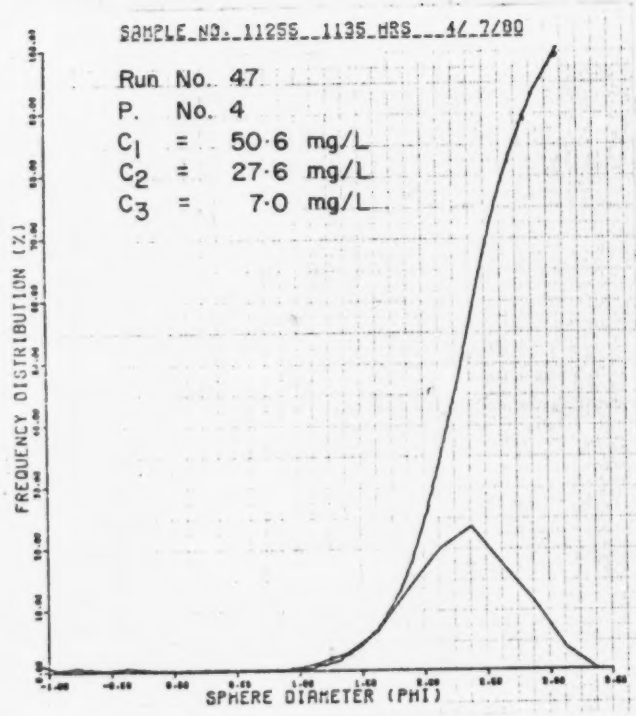
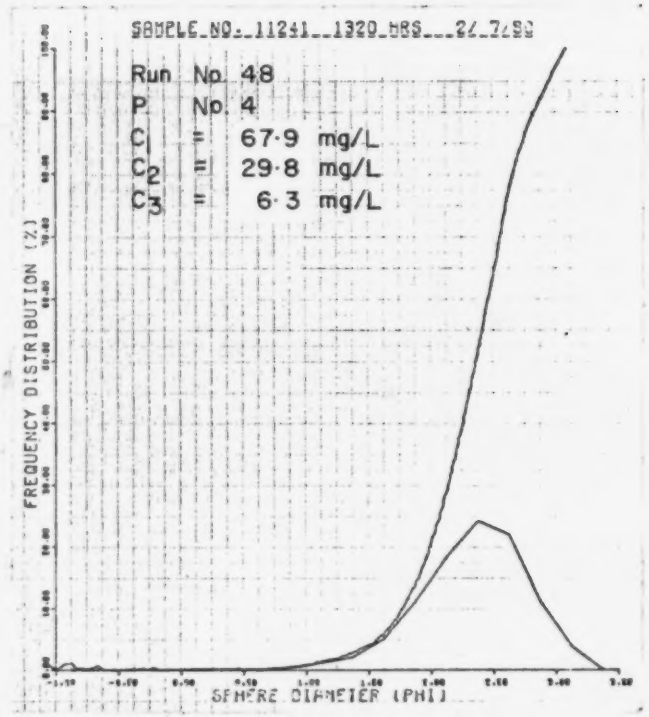


FIGURE 25 FREQUENCY DISTRIBUTION OF PARTICLES



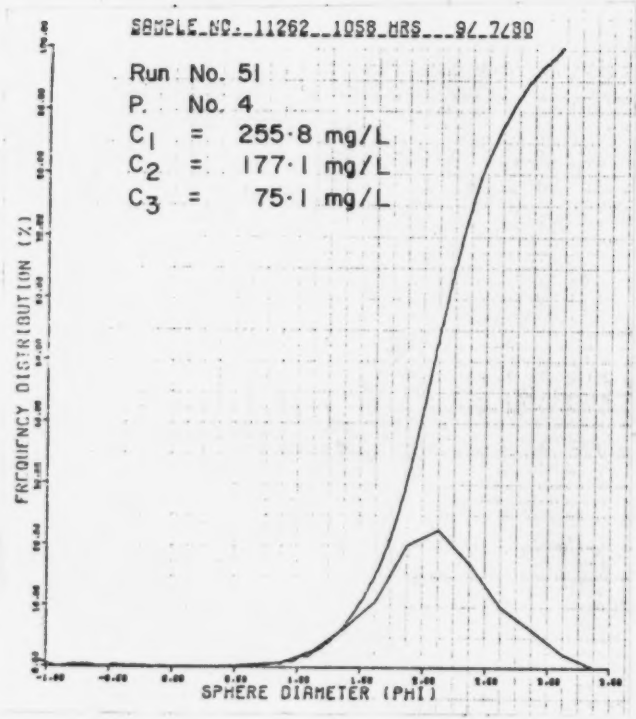
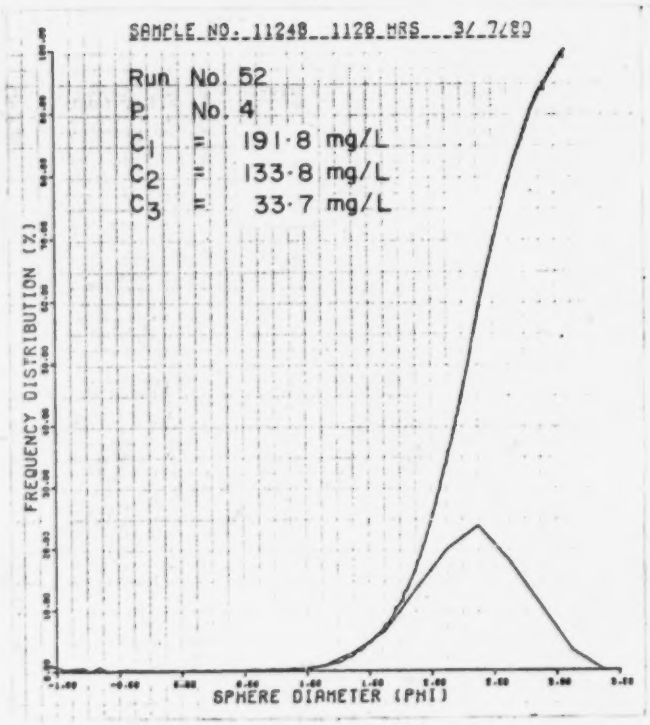

SAMPLE NO.: 11262 1058 HRS 97 7 88
Run No. 51
P. No. 4
C1 = 255·8 mg/L
C2 = 177·1 mg/L
C3 = 75·1 mg/L
FREQUENCY DISTRIBUTION (%)
SPHERE DIAMETER (PHI)

FIGURE 26 FREQUENCY DISTRIBUTION OF PARTICLES


SAMPLE NO.: 11248 1128 HRS 27 7 80
Run No. 52
P. No. 4
C1 = 191·8 mg/L
C2 = 133·8 mg/L
C3 = 33·7 mg/L
FREQUENCY DISTRIBUTION (%)
SPHERE DIAMETER (PHI)

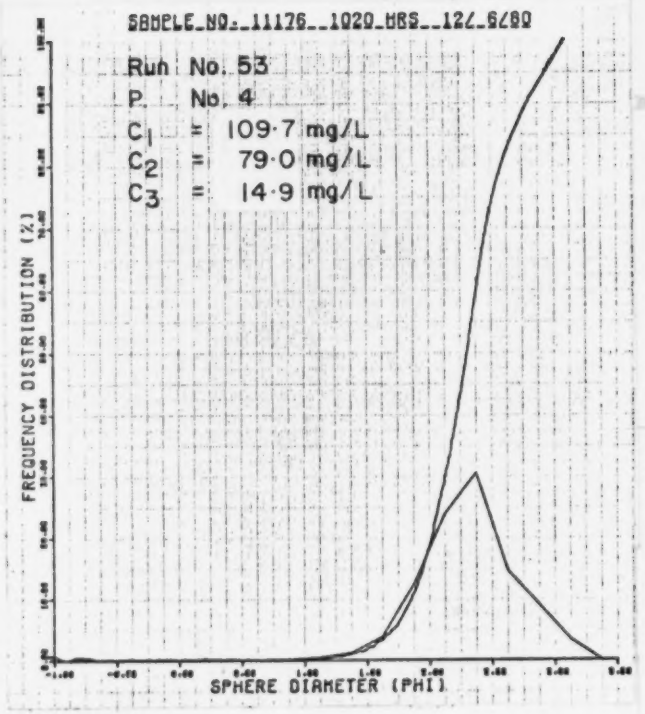


FIGURE 27 FREQUENCY DISTRIBUTION OF PARTICLES

LEGEND

P : Sampling Point.
C_1 : Concentration of total solids.
C_2 : Concentration of solids $d \geq 0{\cdot}088$ mm
C_3 : Concentration of solids $d \geq 0{\cdot}2$ mm
ϕ : $-\log_2 d$

Conversion of Phi Values into Millimeters

phi	d mm
−1·00	2·00
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−0·50	1·41
−0·25	0·19
0	1·00
+0·25	0·84
+0·5	0·71
+0·75	0·60
+1·00	0·50
+1·25	0·42
+1·50	0·35
+1·75	0·30
+2·00	0·25
+2·50	0·177
+3·00	0·125
+3·50	0·088

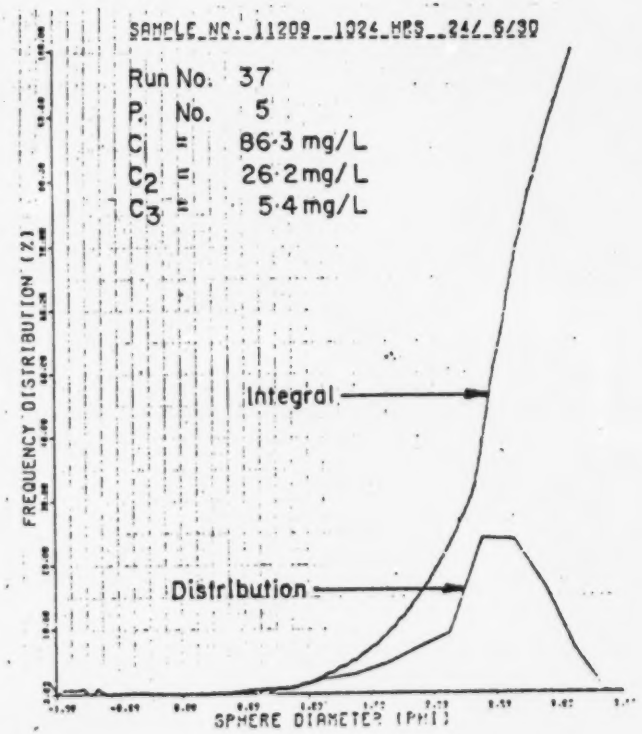
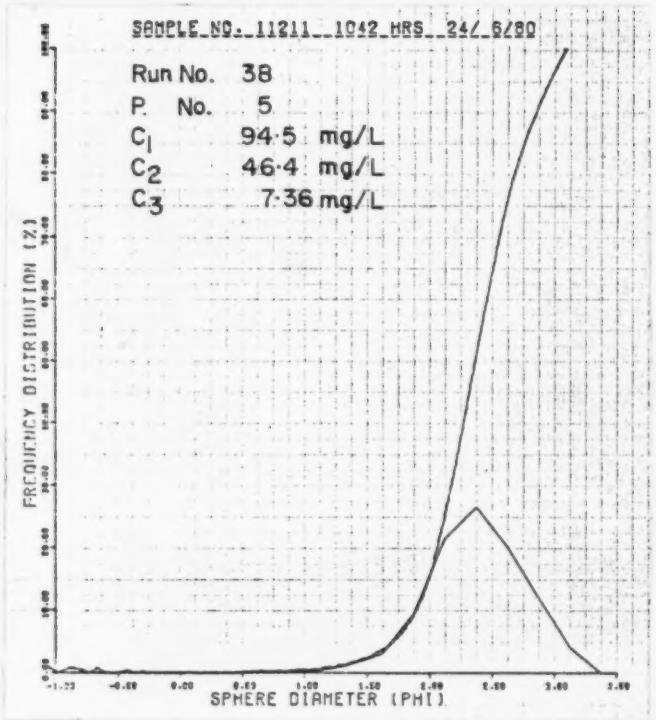


FIGURE 28 FREQUENCY DISTRIBUTION OF PARTICLES



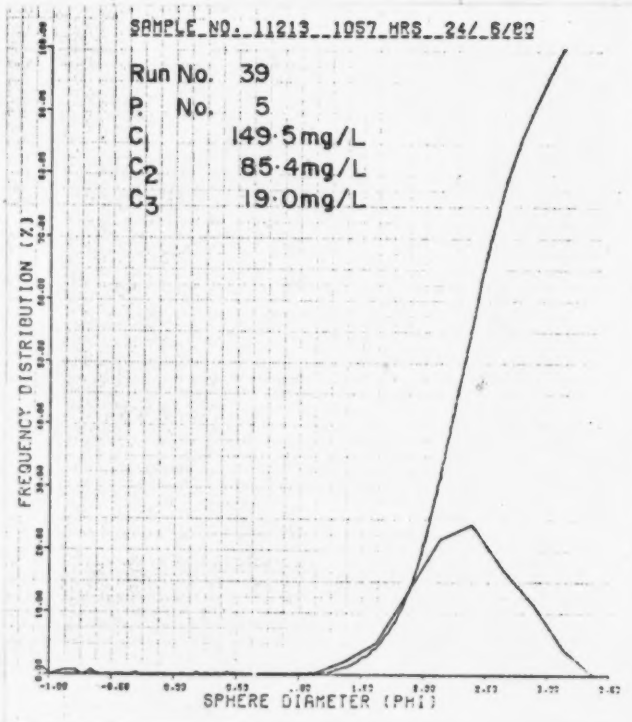
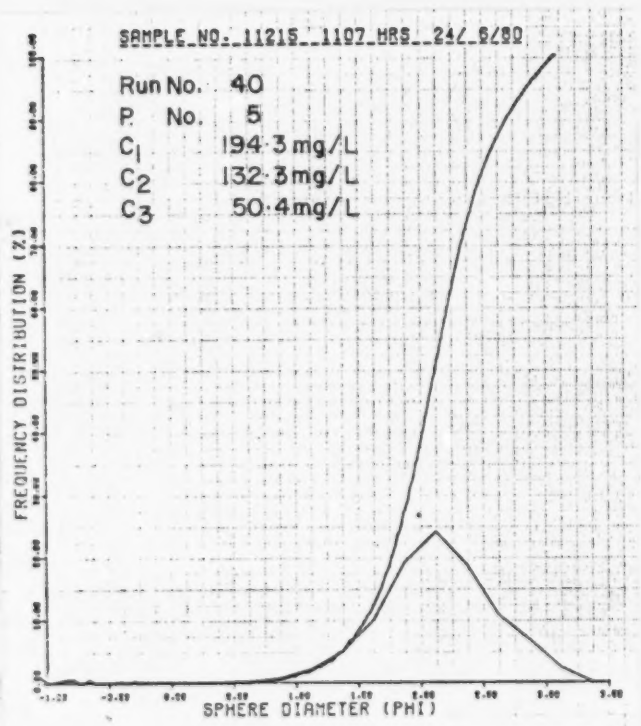


FIGURE 29 FREQUENCY DISTRIBUTION OF PARTICLES



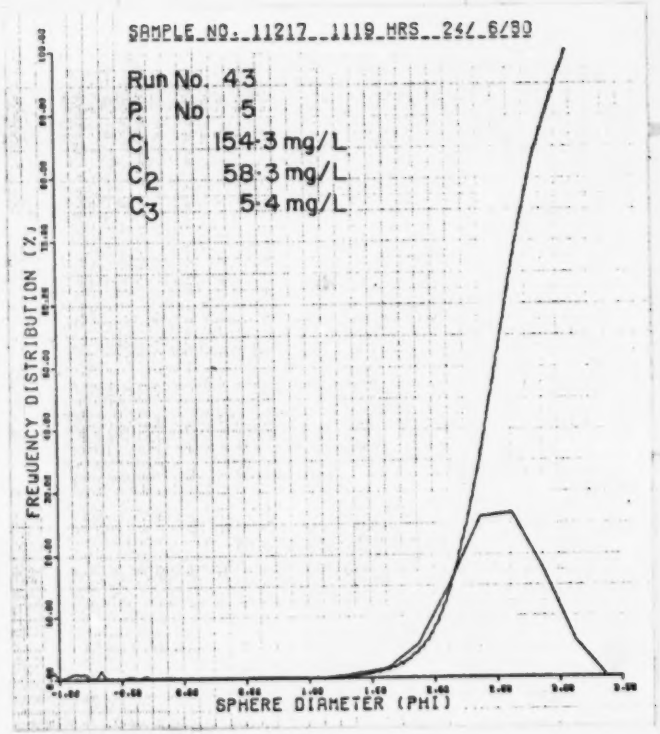
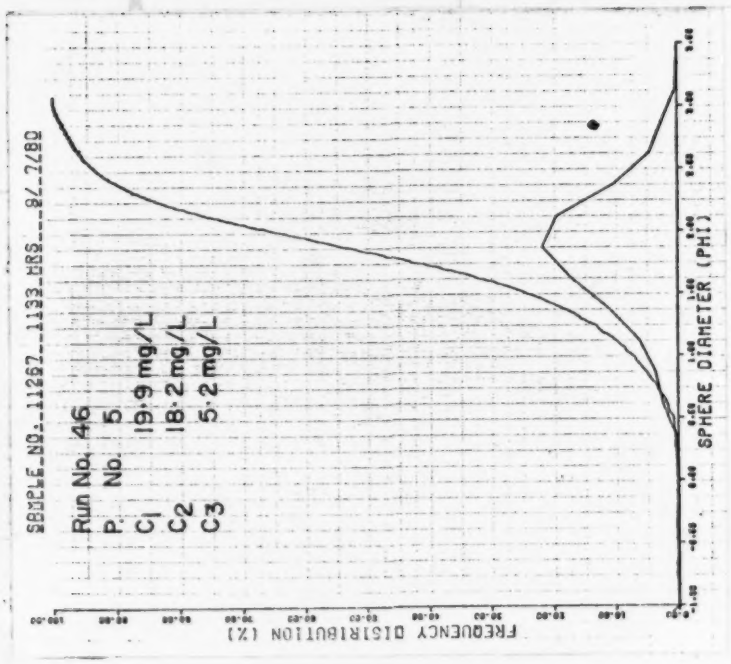


FIGURE 30 FREQUENCY DISTRIBUTION OF PARTICLES



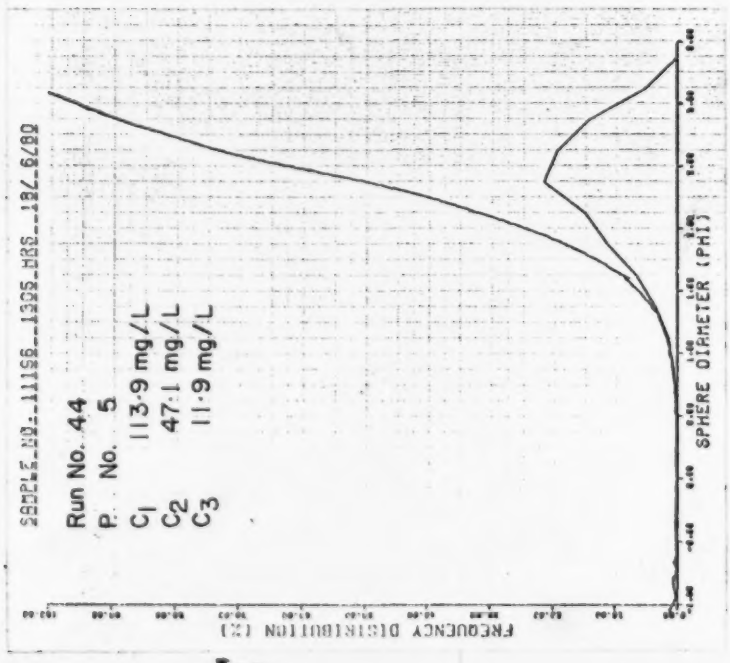
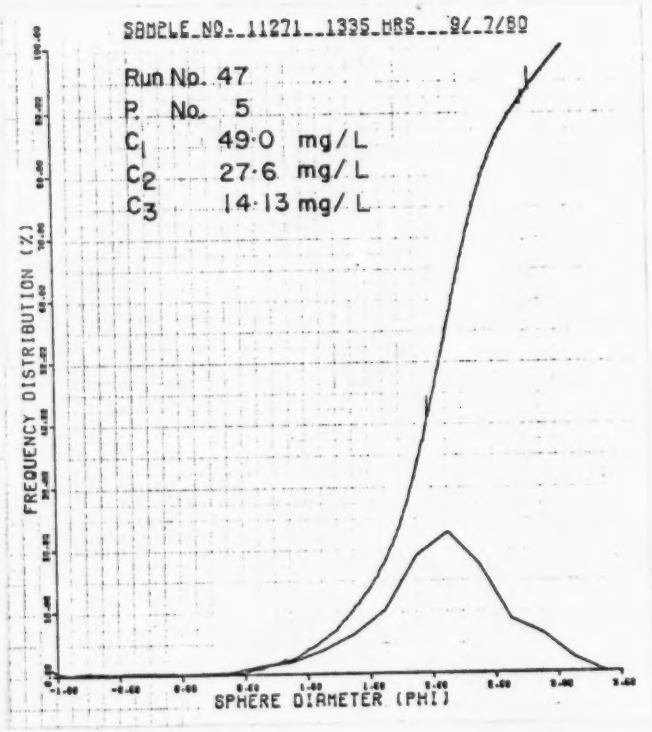


FIGURE 31 FREQUENCY DISTRIBUTION OF PARTICLES



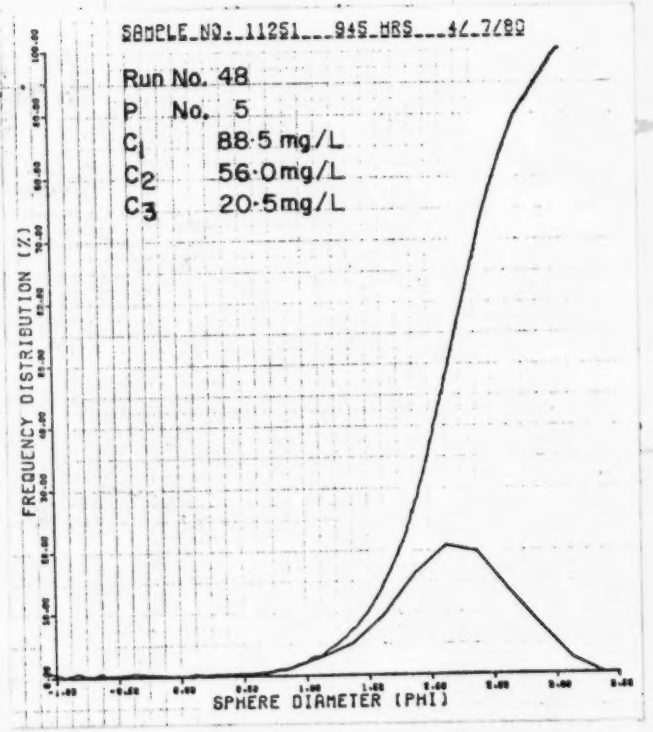
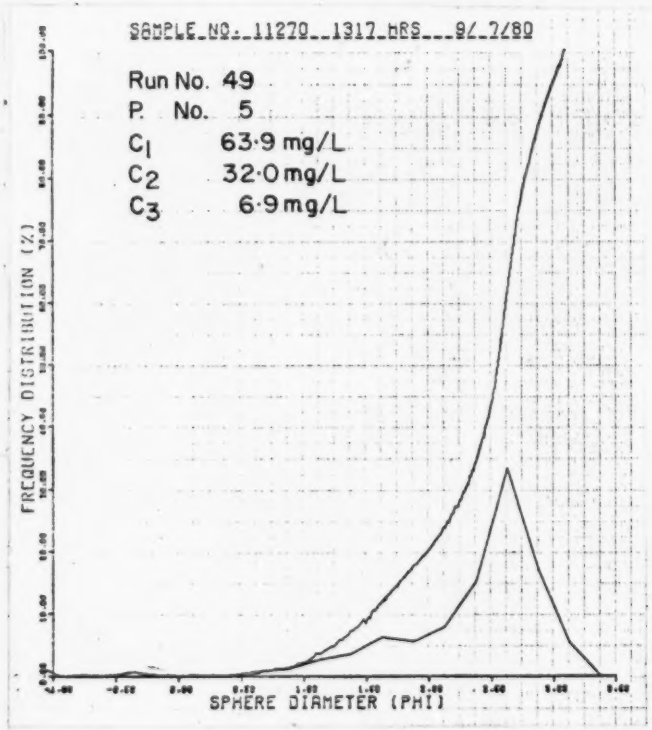


FIGURE 32 FREQUENCY DISTRIBUTION OF PARTICLES



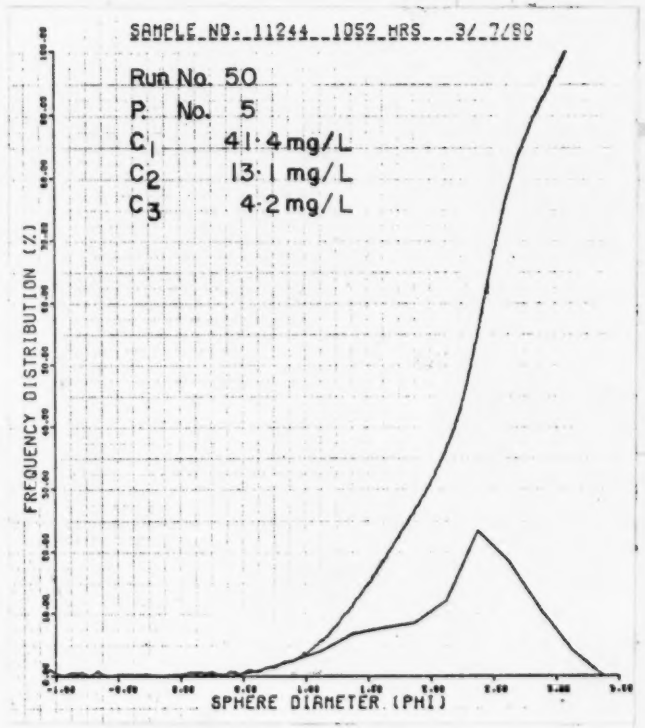


FIGURE 33 FREQUENCY DISTRIBUTION OF PARTICLES

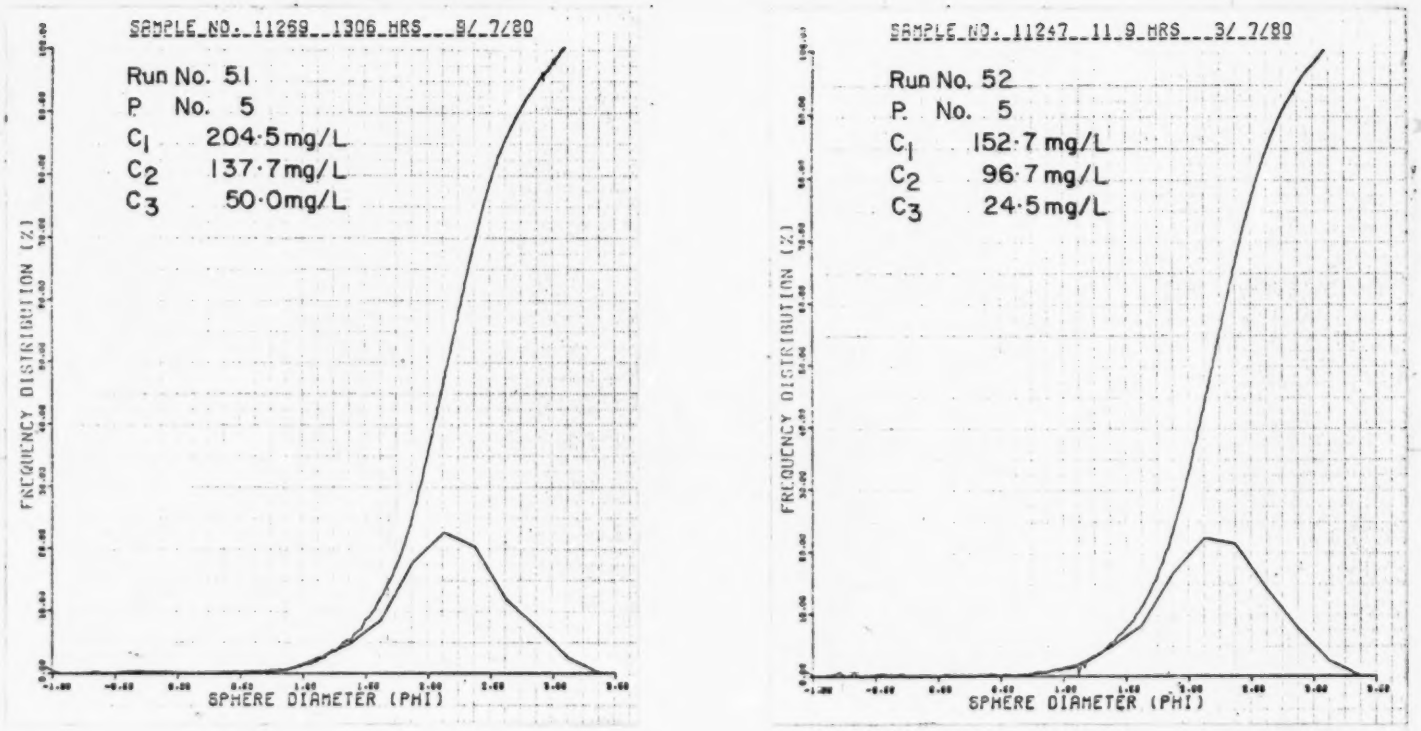
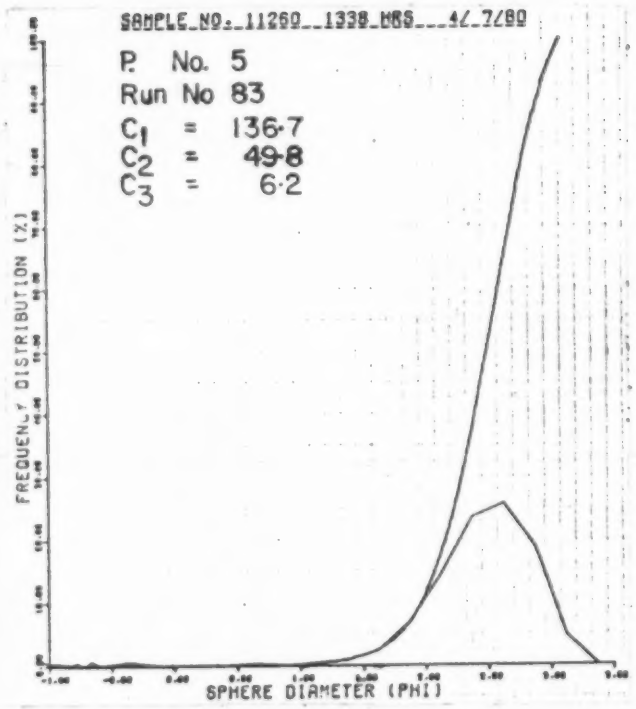


FIGURE 34 FREQUENCY DISTRIBUTION OF PARTICLES



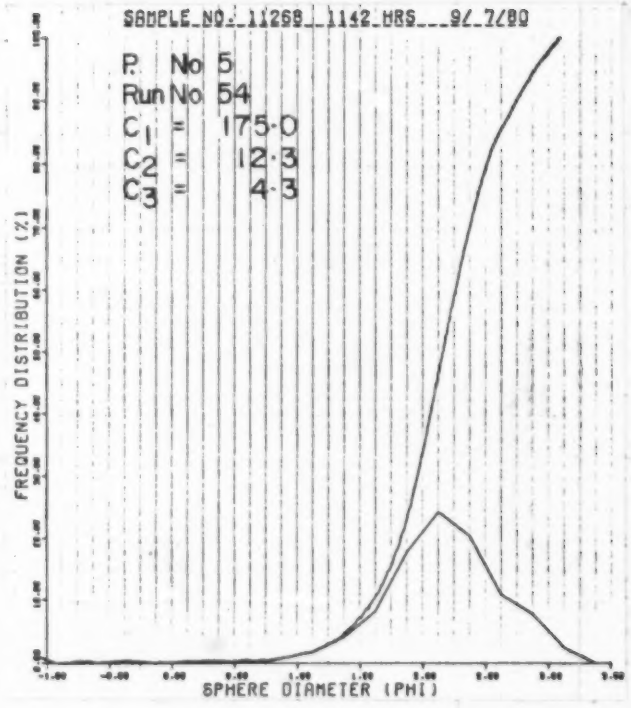
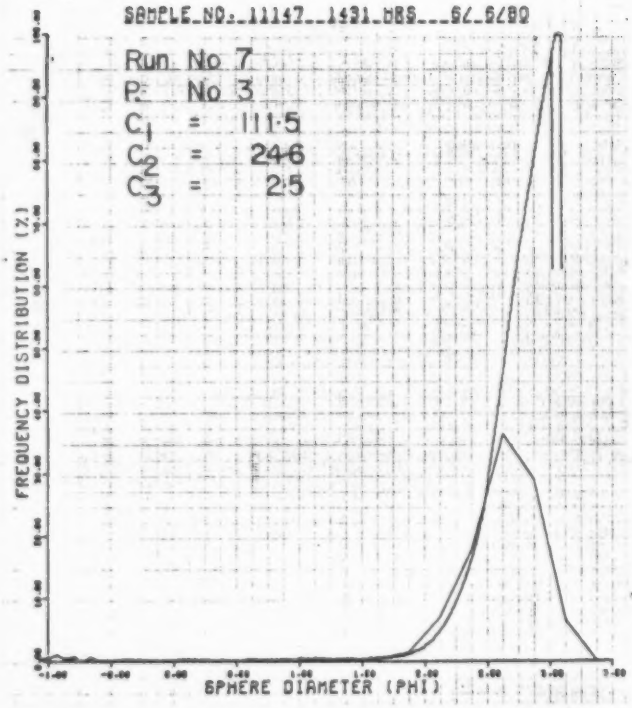


FIGURE 35 FREQUENCY DISTRIBUTION OF PARTICLES



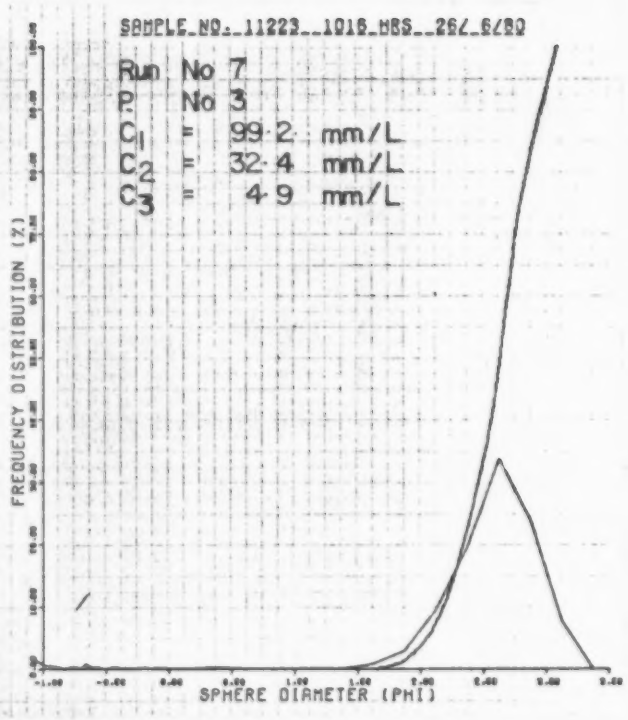
LEGEND

P : Sampling Point.
C_1 : Concentration of total solids.
C_2 : Concentration of solids $d \geqslant 0{\cdot}088$. mm
C_3 : Concentration of solids $d \geqslant 0{\cdot}2$. mm
$\phi : -\log_2 d$

Conversion of Phi Values into Millimeters

phi	d mm
− 1·00	2·00
− 0·75	1·68
− 0·50	1·41
− 0·25	0·19
0	1·00
+ 0·25	0·84
+ 0·5	0·71
+ 0·75	0·60
+ 1·00	0·50
+ 1·25	0·42
+ 1·50	0·35
+ 1·75	0·30
+ 2·00	0·25
+ 2·50	0·177
+ 3·00	0·125
+ 3·50	0·088

FIGURE 36 FREQUENCY DISTRIBUTION OF PARTICLES



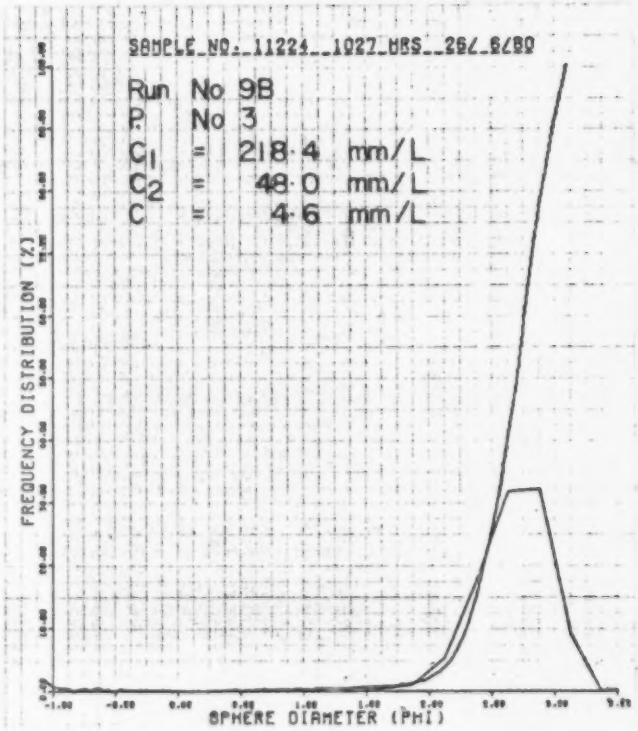
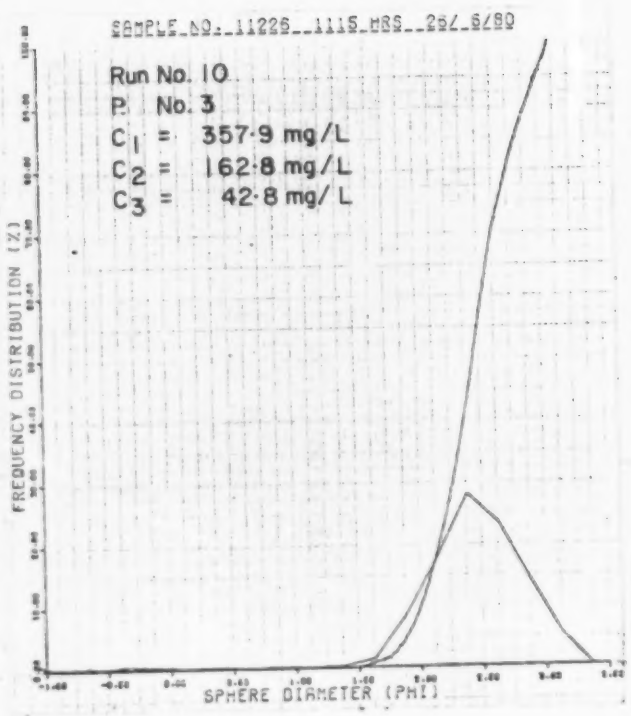


FIGURE 37 FREQUENCY DISTRIBUTION OF PARTICLES


SAMPLE NO. 11226 1115 HRS 29/ 8/80
Run No. 10
P. No. 3
C1 = 357·9 mg/L
C2 = 162·8 mg/L
C3 = 42·8 mg/ L
FREQUENCY DISTRIBUTION (%)
SPHERE DIAMETER (PHI)

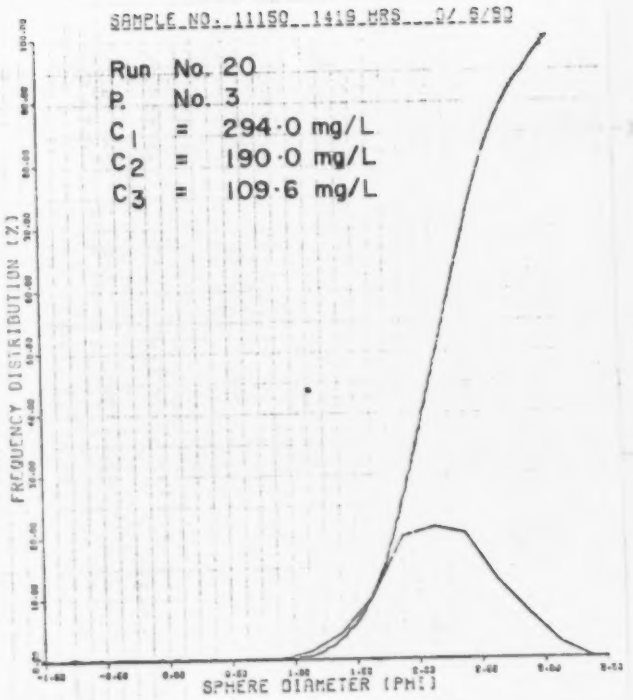
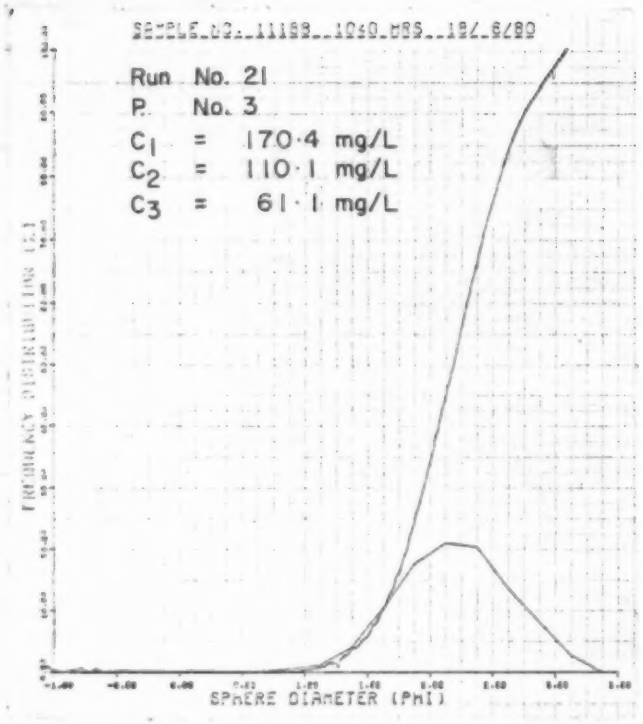


FIGURE 38 FREQUENCY DISTRIBUTION OF PARTICLES



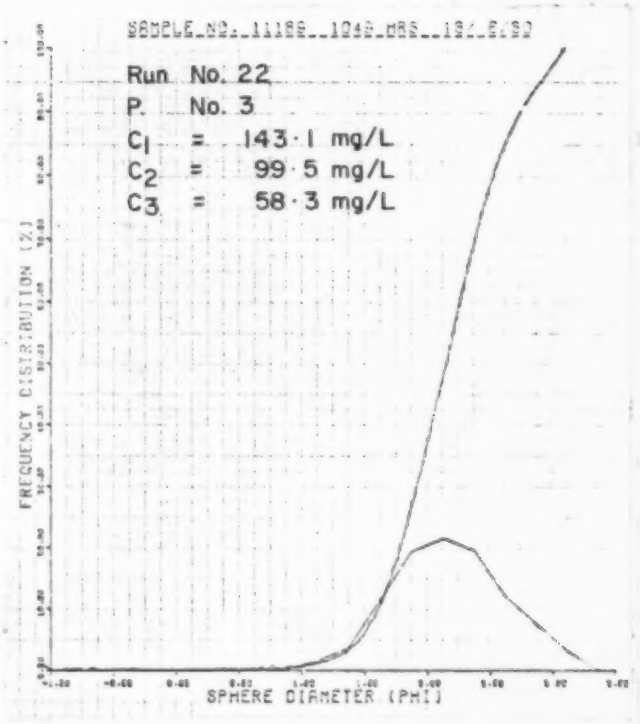
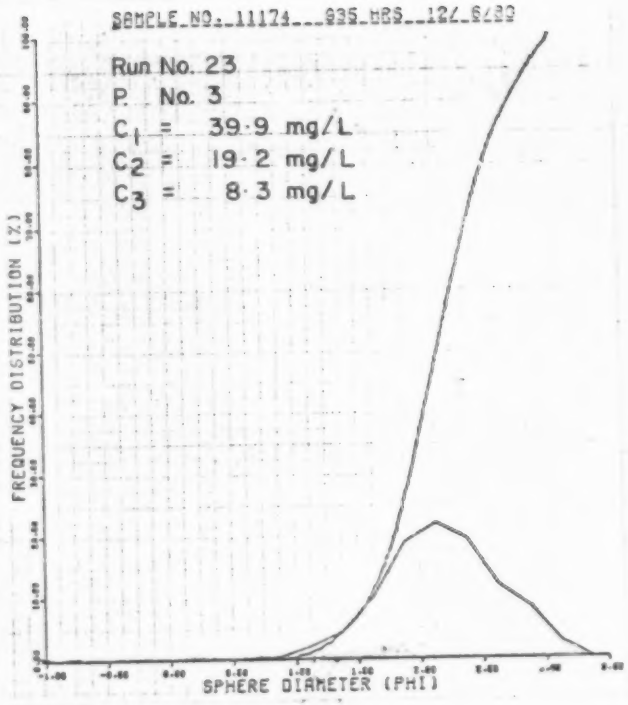


FIGURE 39. FREQUENCY DISTRIBUTION OF PARTICLES



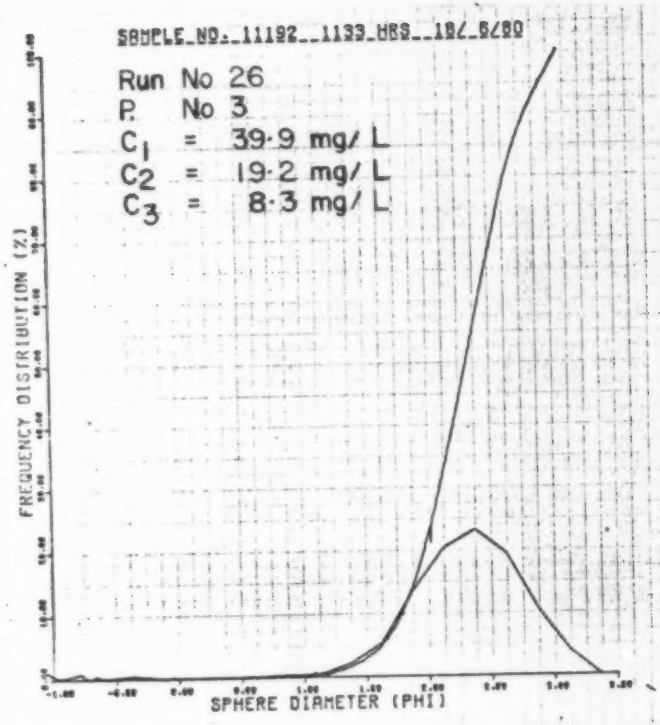
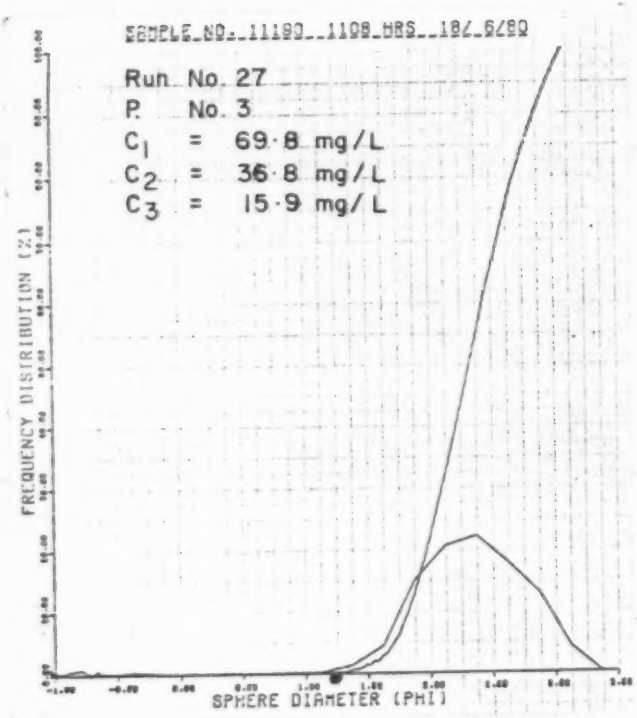


FIGURE 40 FREQUENCY DISTRIBUTION OF PARTICLES



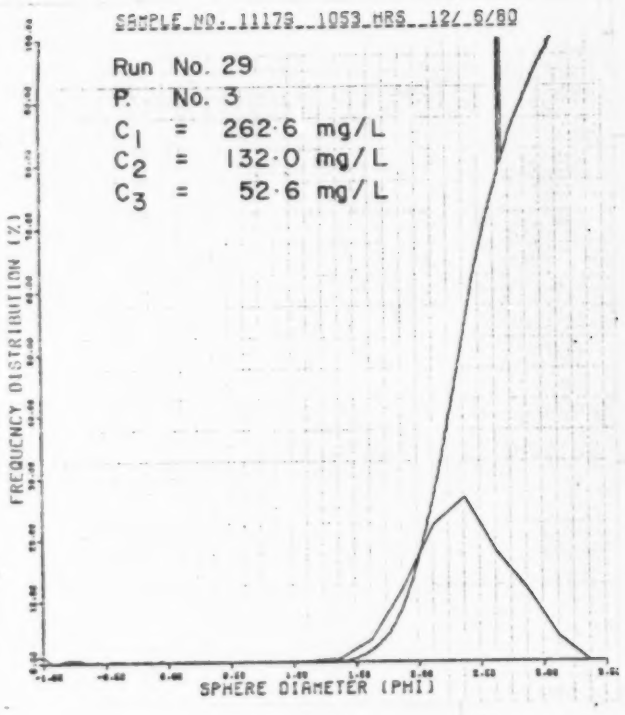
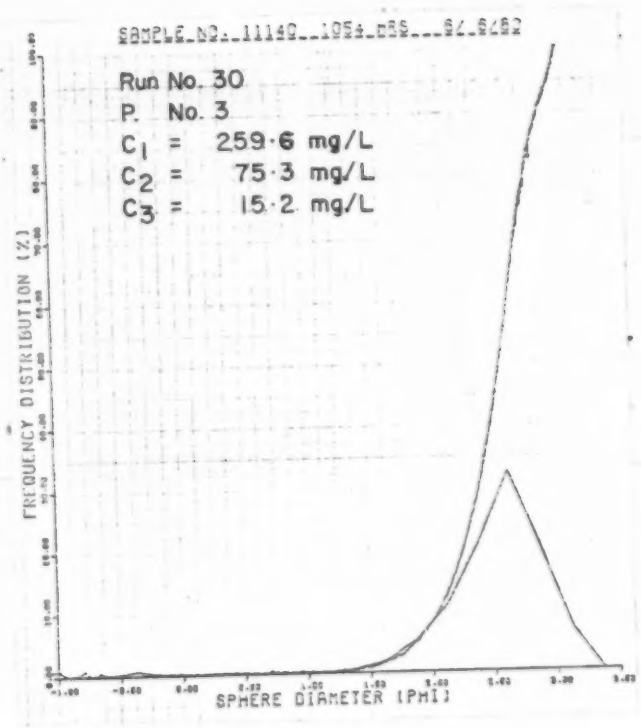


FIGURE 41 FREQUENCY DISTRIBUTION OF PARTICLES



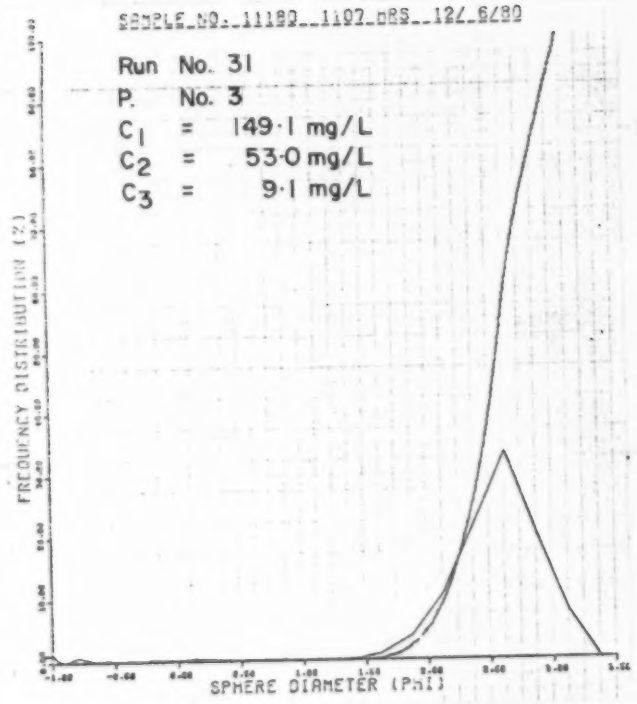
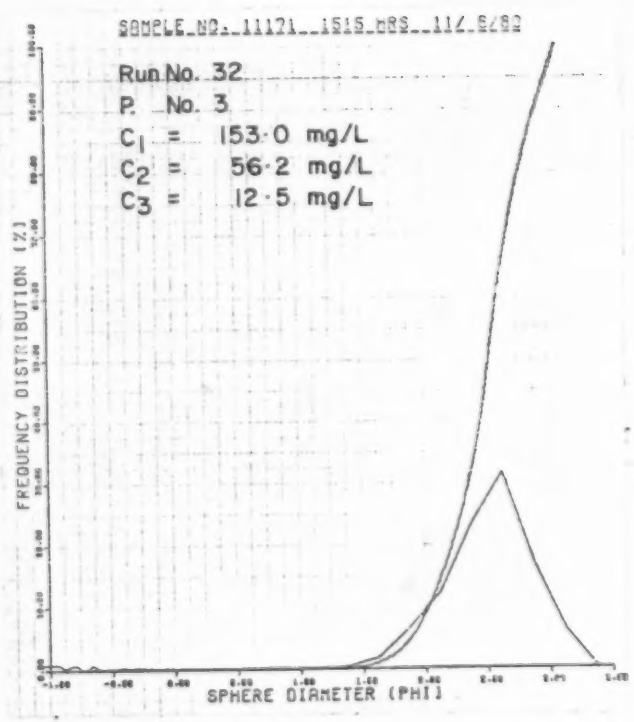


FIGURE 42 FREQUENCY DISTRIBUTION OF PARTICLES



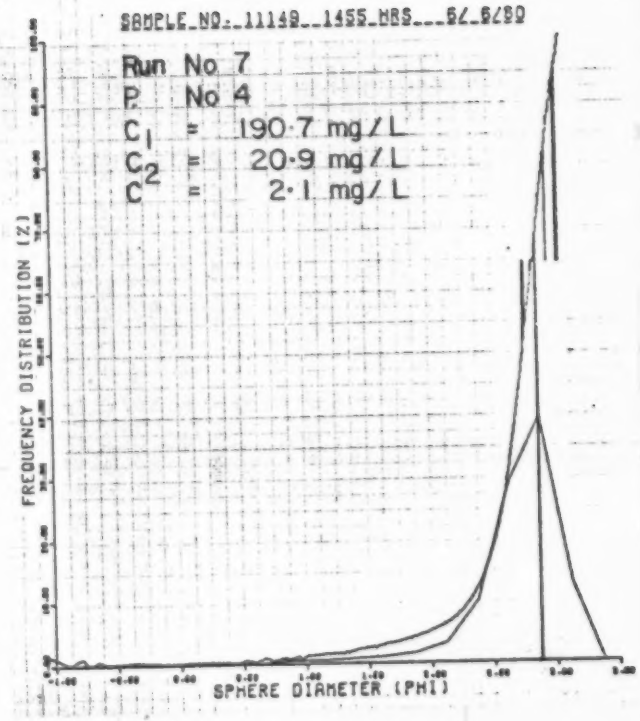
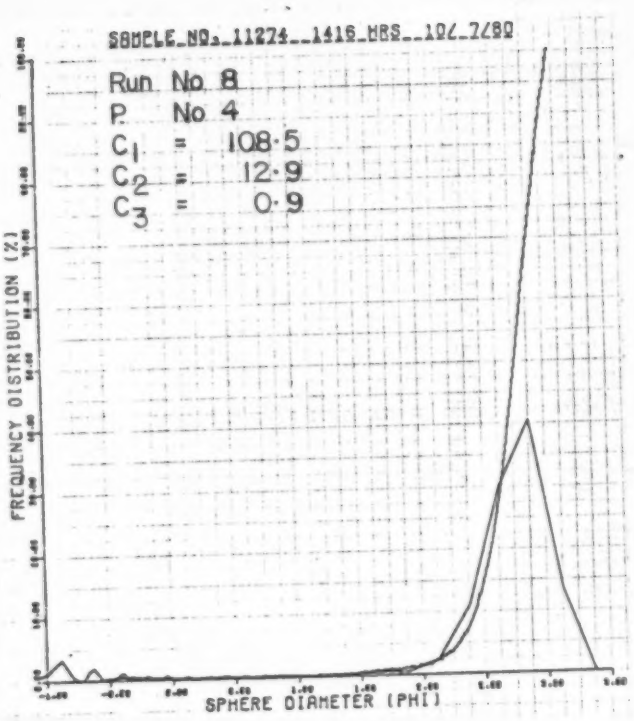


FIGURE 43 FREQUENCY DISTRIBUTION OF PARTICLES



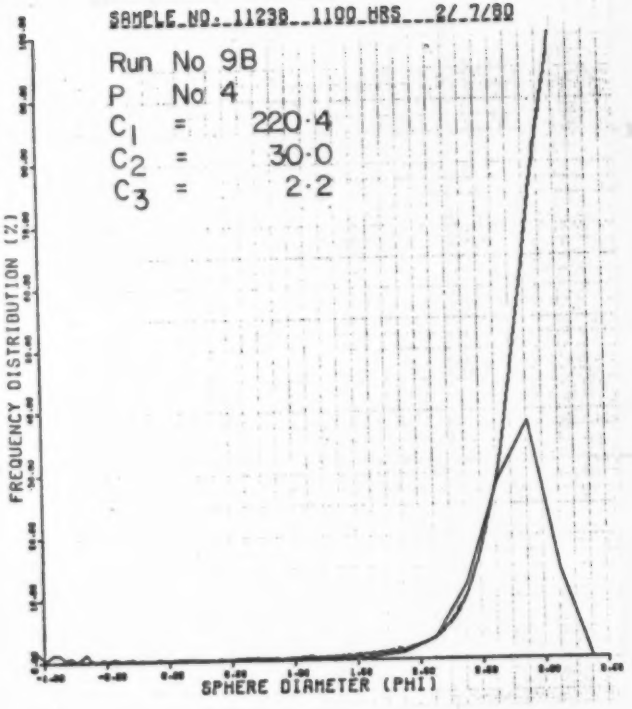
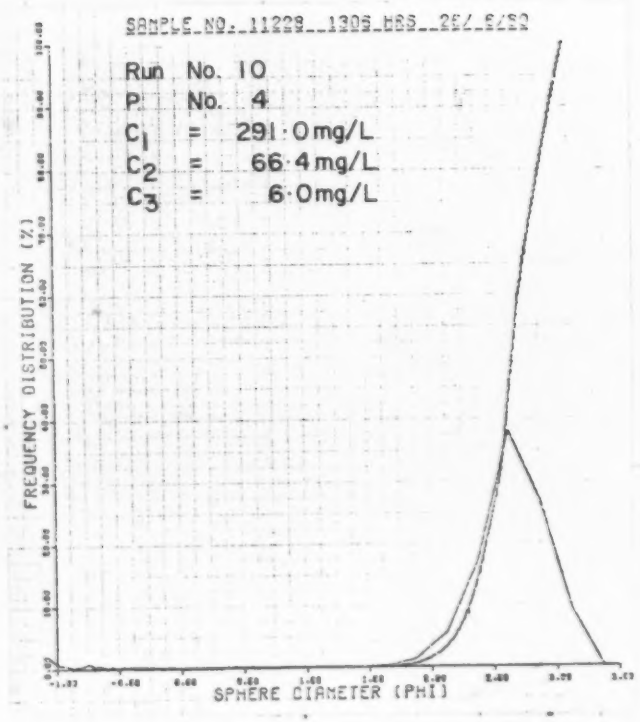


FIGURE 44 FREQUENCY DISTRIBUTION OF PARTICLES



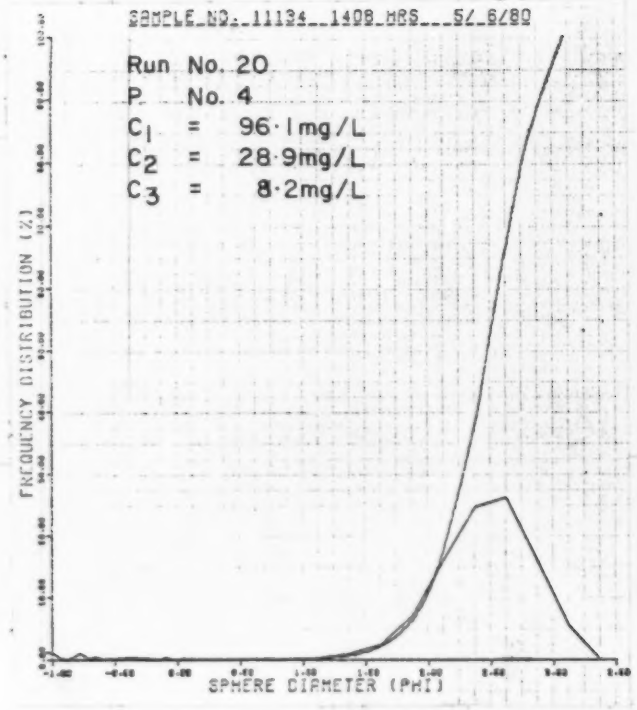
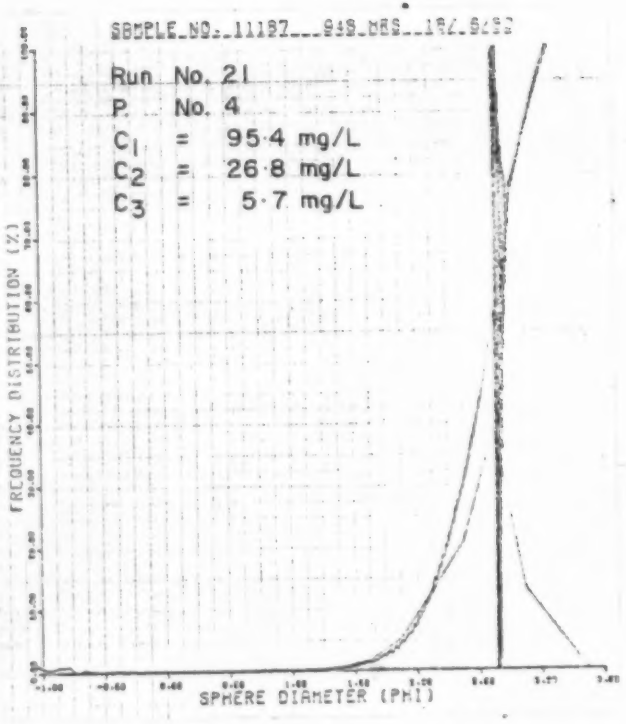


FIGURE 45 FREQUENCY DISTRIBUTION OF PARTICLES



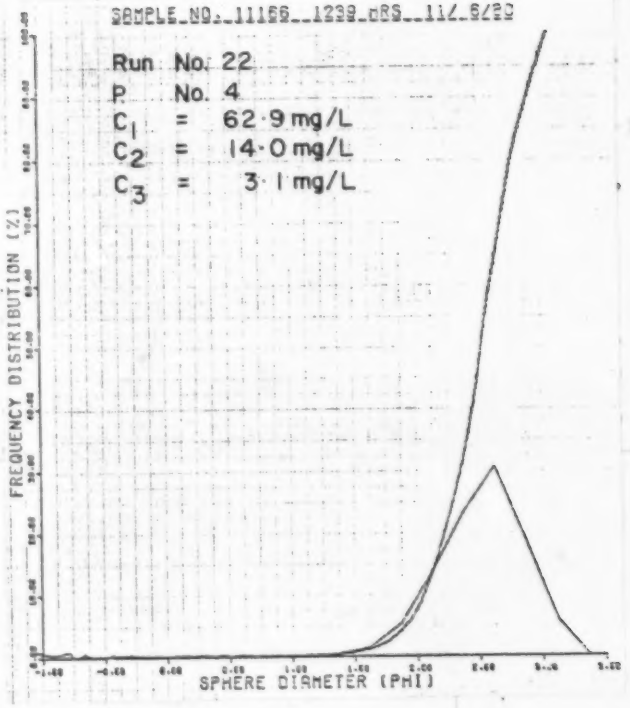
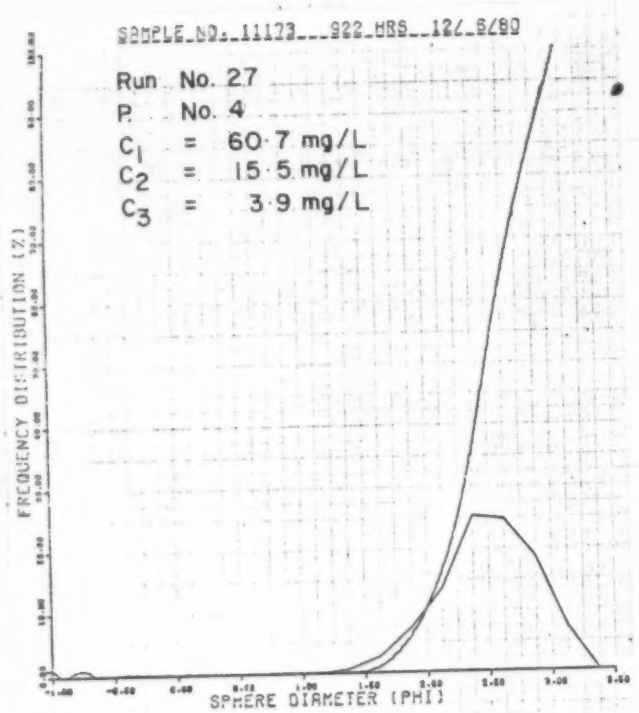


FIGURE 46 FREQUENCY DISTRIBUTION OF PARTICLES



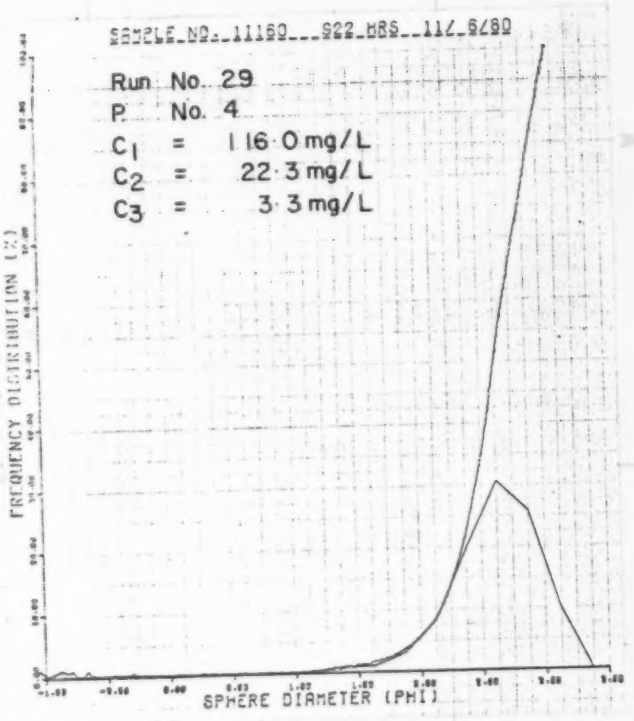


FIGURE 47 FREQUENCY DISTRIBUTION OF PARTICLES

LEGEND

P : Sampling Point.
C_1 : Concentration of total solids.
C_2 : Concentration of solids $d \geq 0{\cdot}088$. mm
C_3 : Concentration of solids $d \geq 0{\cdot}2$. mm

$\phi = -\log_2 d$

Conversion of Phi Values into Millimeters

phi	d mm
− 1·00	2·00
− 0·75	1·68
− 0·50	1·41
− 0·25	0·19
0	1·00
+ 0·25	0·84
+ 0·5	0·71
+ 0·75	0·60
+ 1·00	0·50
+ 1·25	0·42
+ 1·50	0·35
+ 1·75	0·30
+ 2·00	0·25
+ 2·50	0·177
+ 3·00	0·125
+ 3·50	0·088

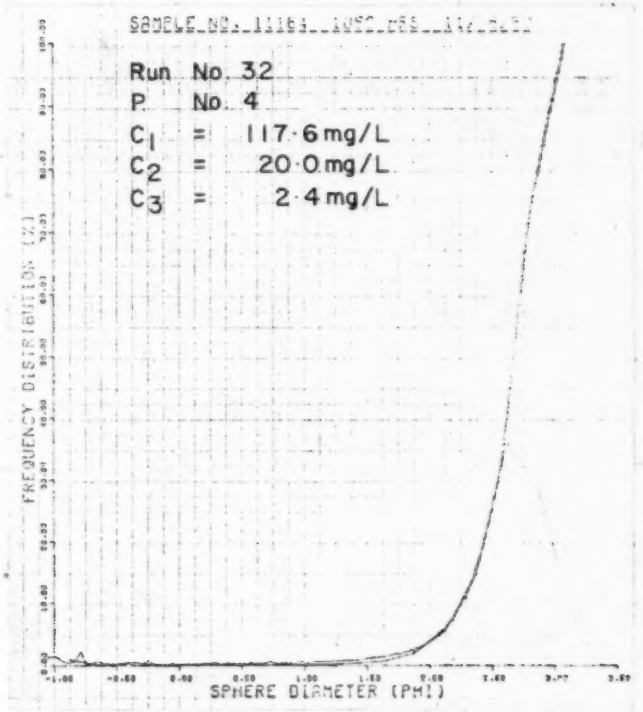


FIGURE 48 FREQUENCY DISTRIBUTION OF PARTICLES

LEGEND

P : Sampling Point.
C_1 : Concentration of total solids.
C_2 : Concentration of solids $d \geqq 0{\cdot}088$. mm
C_3 : Concentration of solids $d \geqq 0{\cdot}2$. mm

$\phi = -\log_2 d$

Conversion of Phi Values into Millimeters

phi	d mm
− 1·00	2·00
− 0·75	1·68
− 0·50	1·41
− 0·25	0·19
0	1·00
+ 0·25	0·84
+ 0·5	0·71
+ 0·75	0·60
+ 1·00	0·50
+ 1·25	0·42
+ 1·50	0·35
+ 1·75	0·30
+ 2·00	0·25
+ 2·50	0·177
+ 3·00	0·125
+ 3·50	0·088

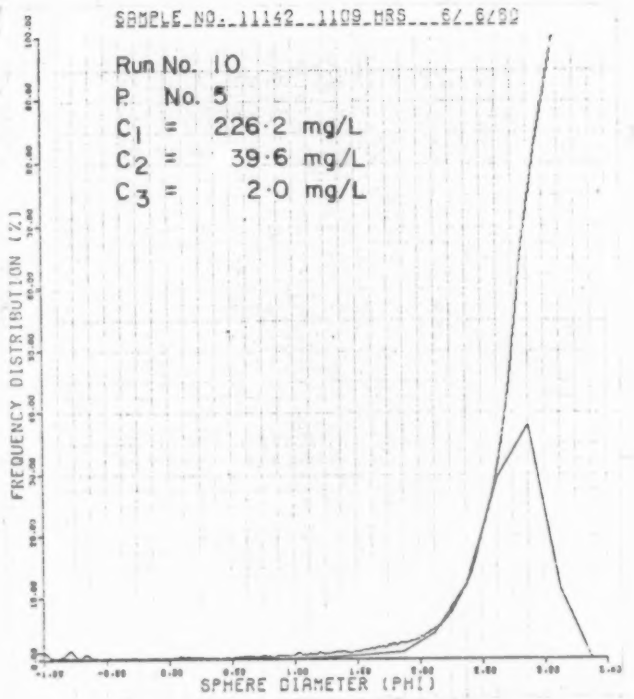
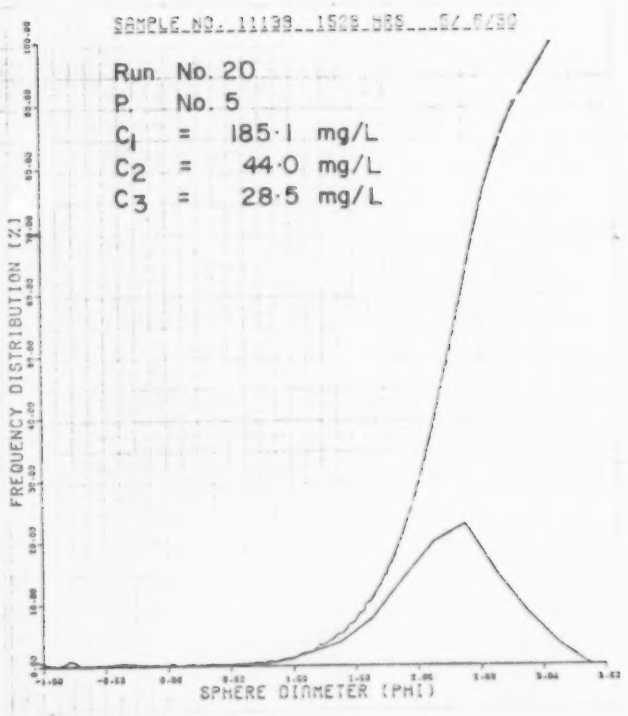


FIGURE 49 FREQUENCY DISTRIBUTION OF PARTICLES



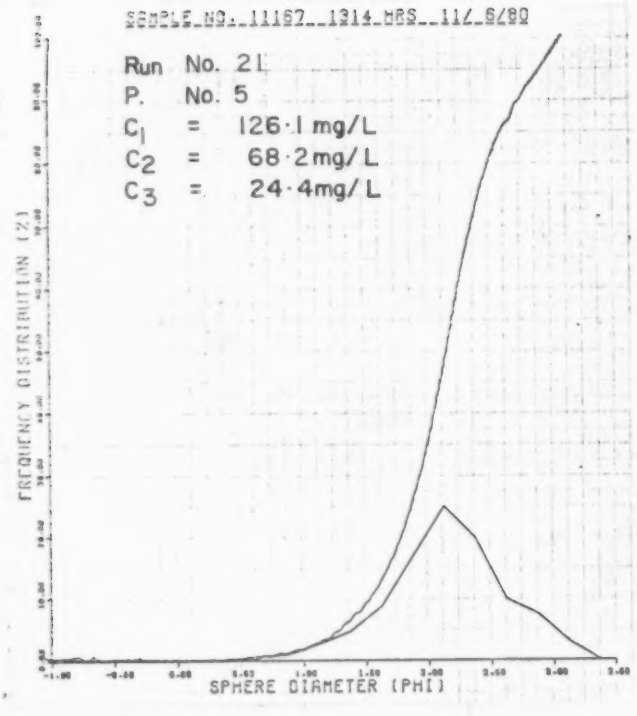


FIGURE 50 FREQUENCY DISTRIBUTION OF PARTICLES

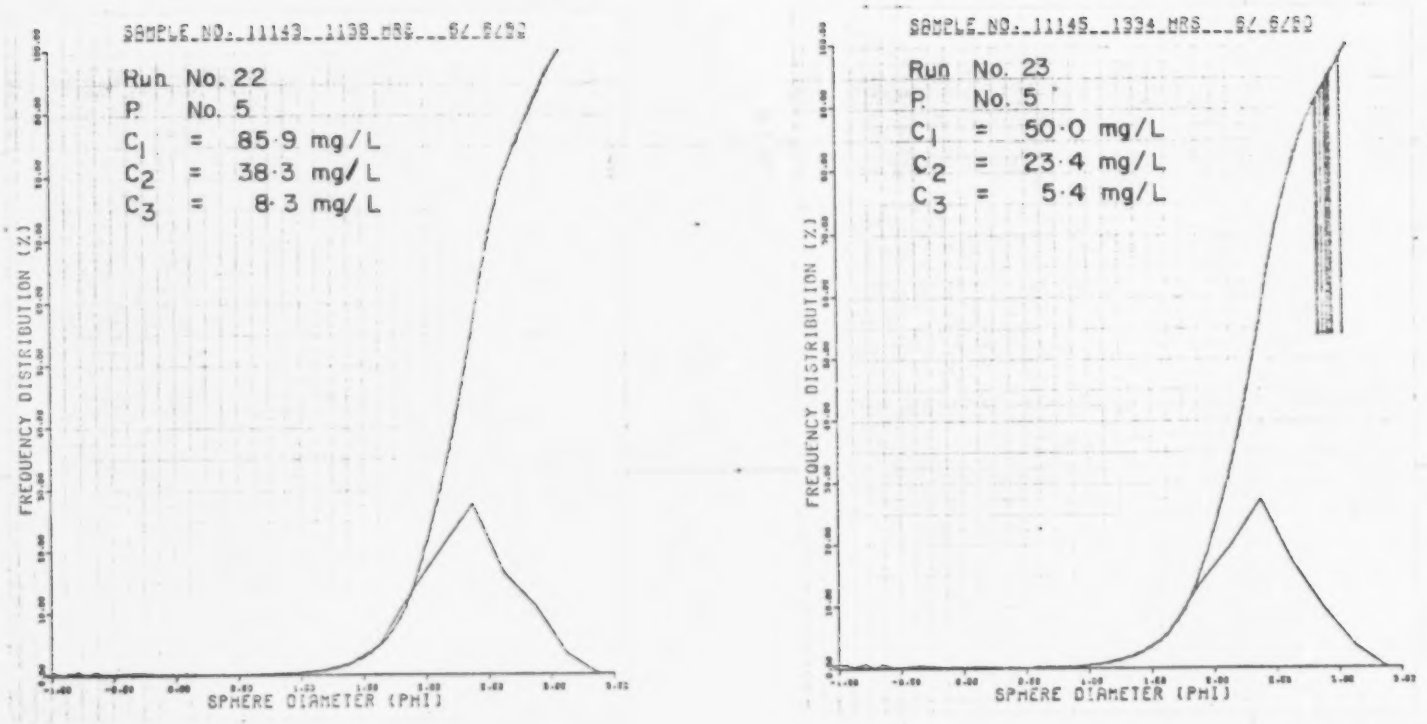
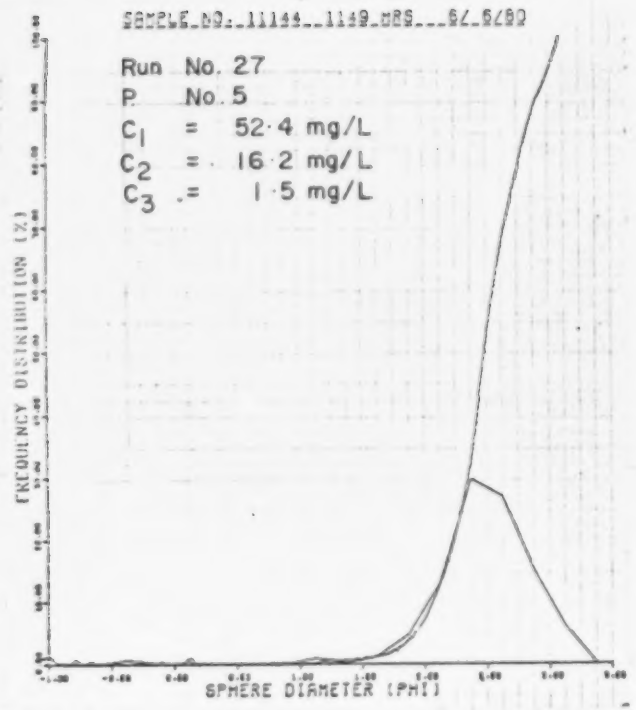


FIGURE 51 FREQUENCY DISTRIBUTION OF SOLIDS



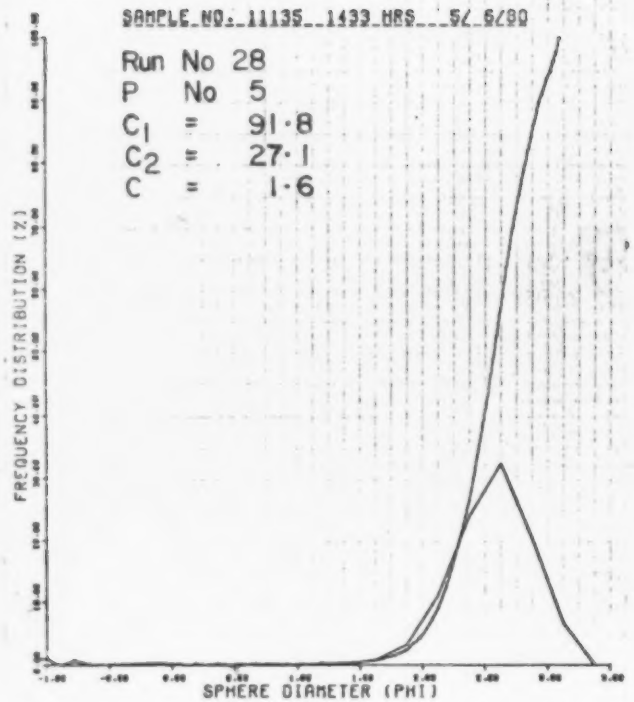


FIGURE 52 FREQUENCY DISTRIBUTION OF PARTICLES

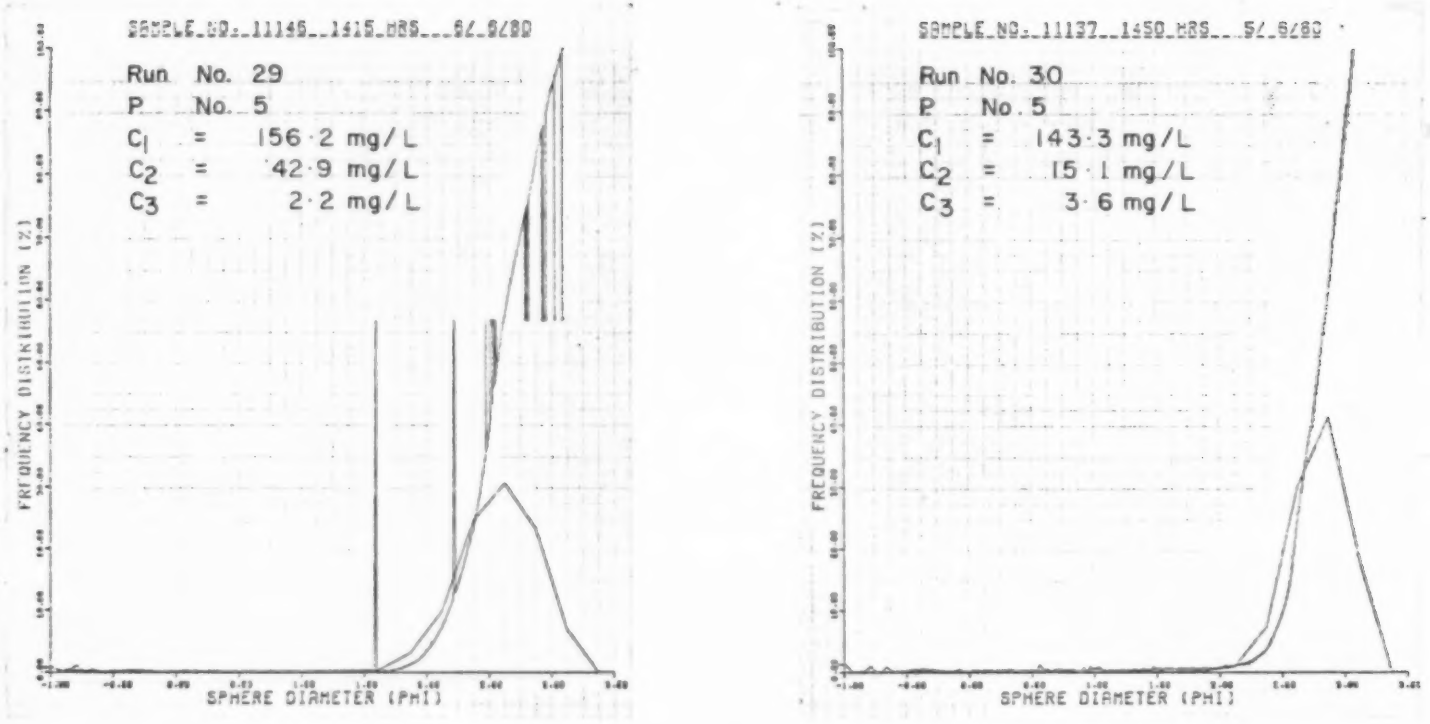
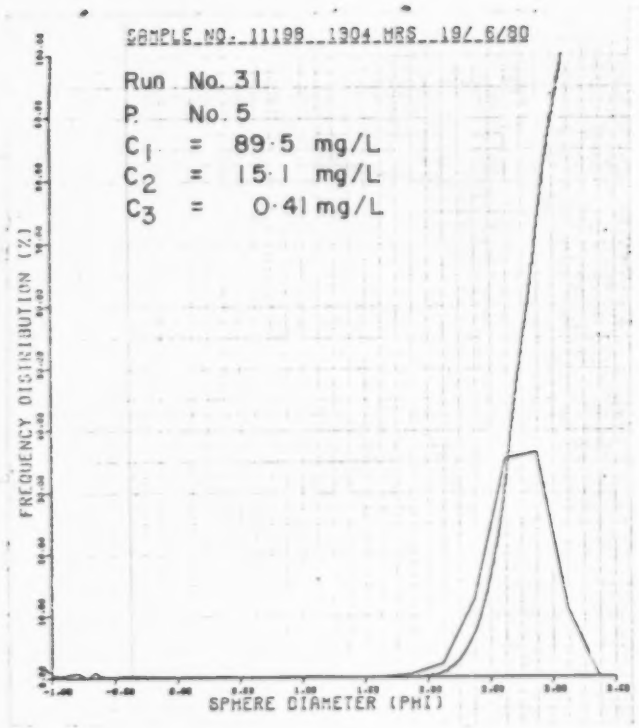


FIGURE 53 FREQUENCY DISTRIBUTION OF PARTICLES



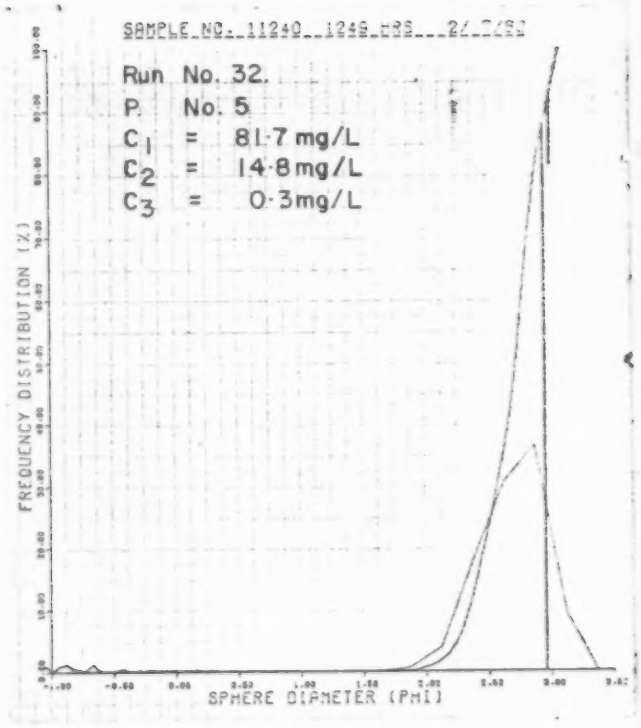


FIGURE 54 FREQUENCY DISTRIBUTION OF PARTICLES

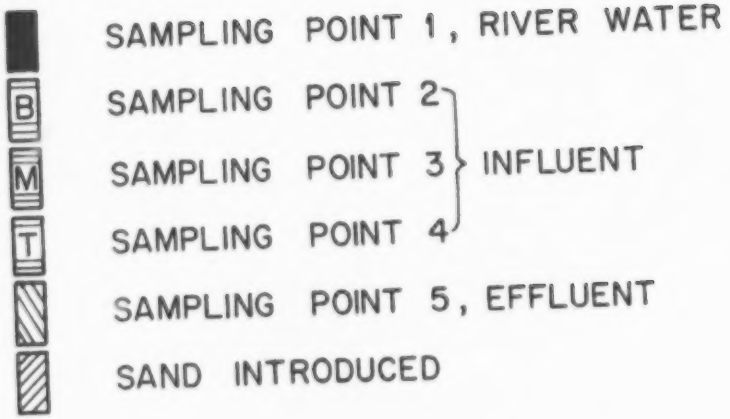


FIGURE 55. CHRONOLOGICAL RECORD OF TEST RUNS

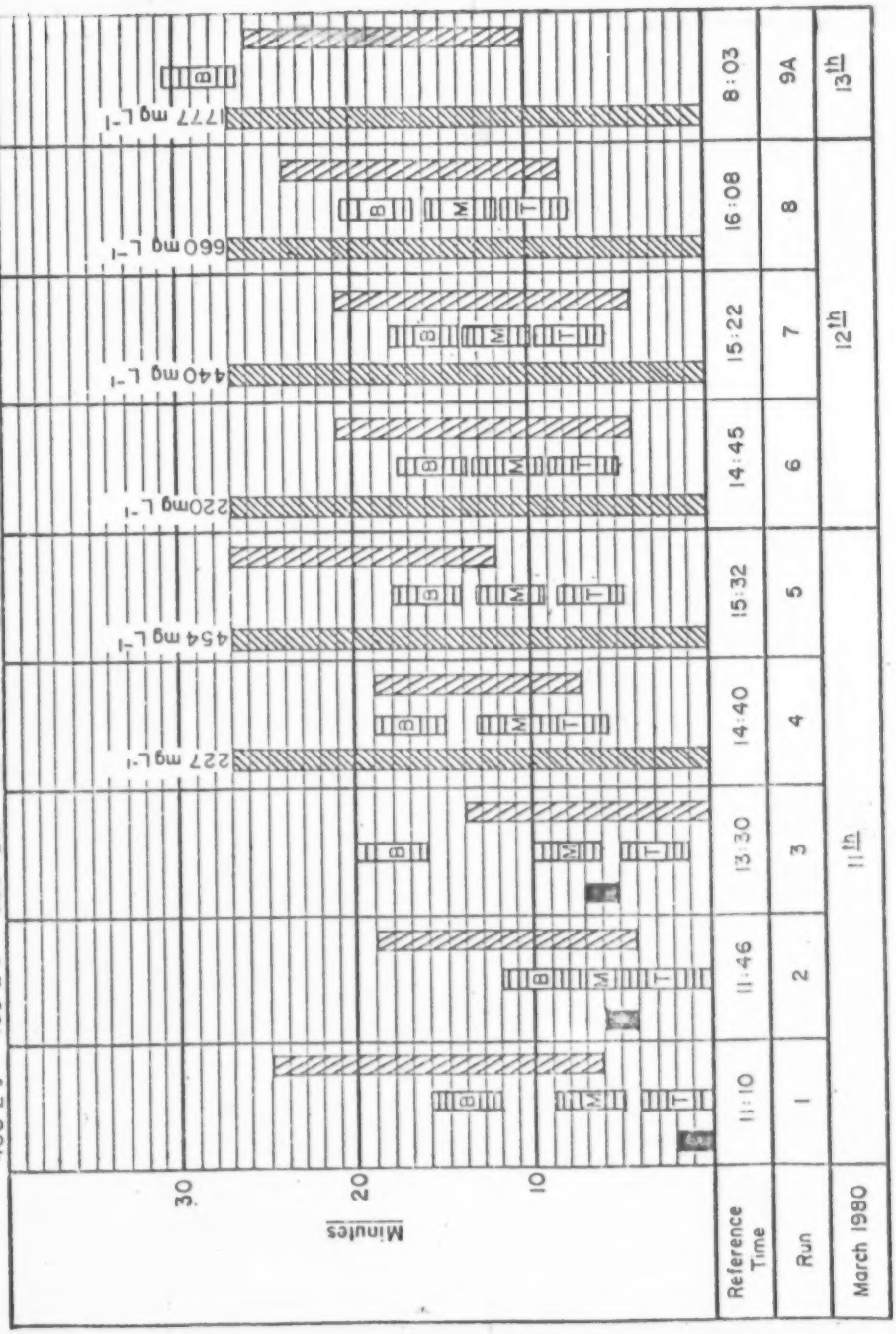


FIGURE 55. CHRONOLOGICAL RECORD OF TEST RUNS (Cont'd)

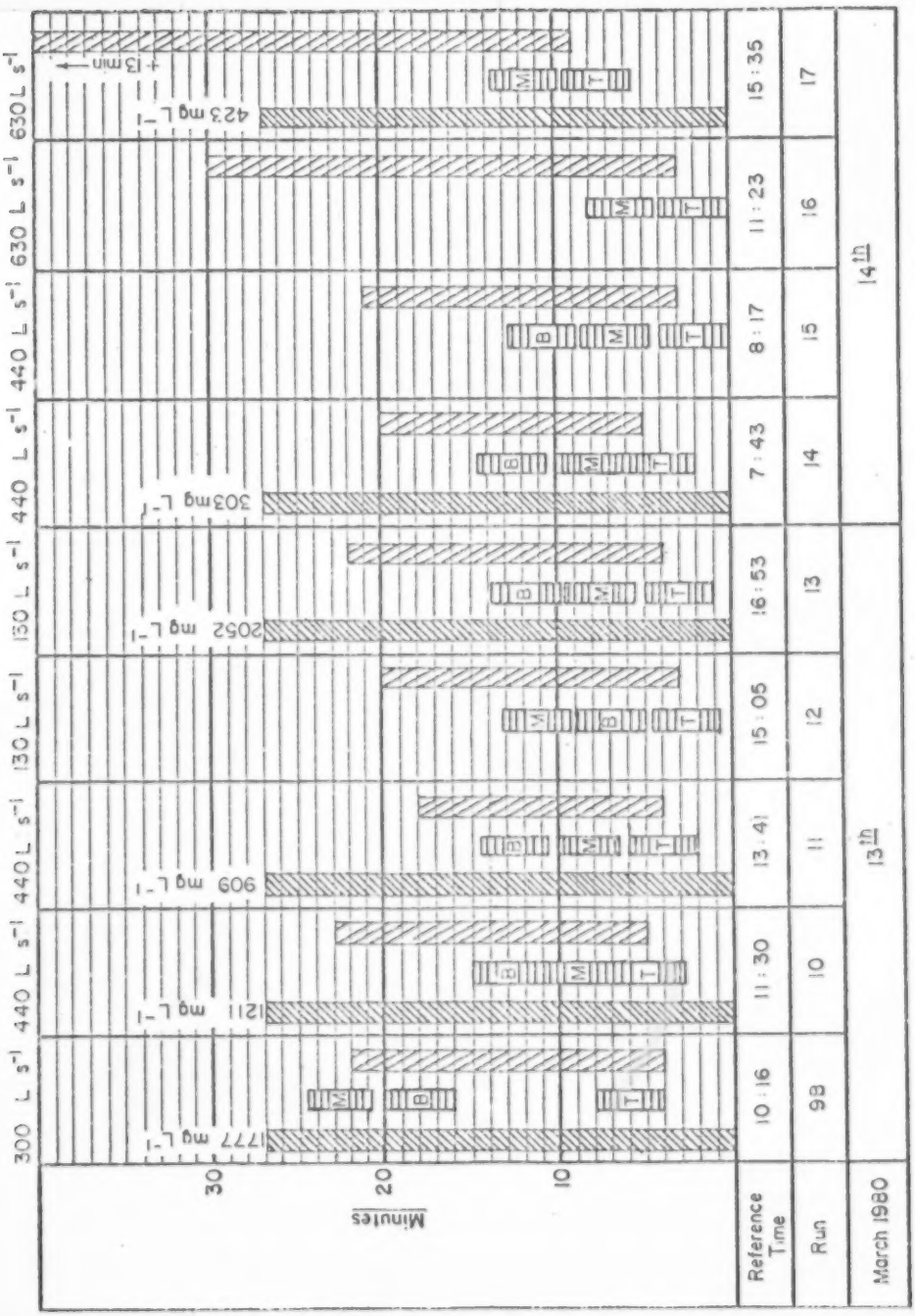


FIGURE 55. CHRONOLOGICAL RECORD OF TEST RUNS (Cont'd)

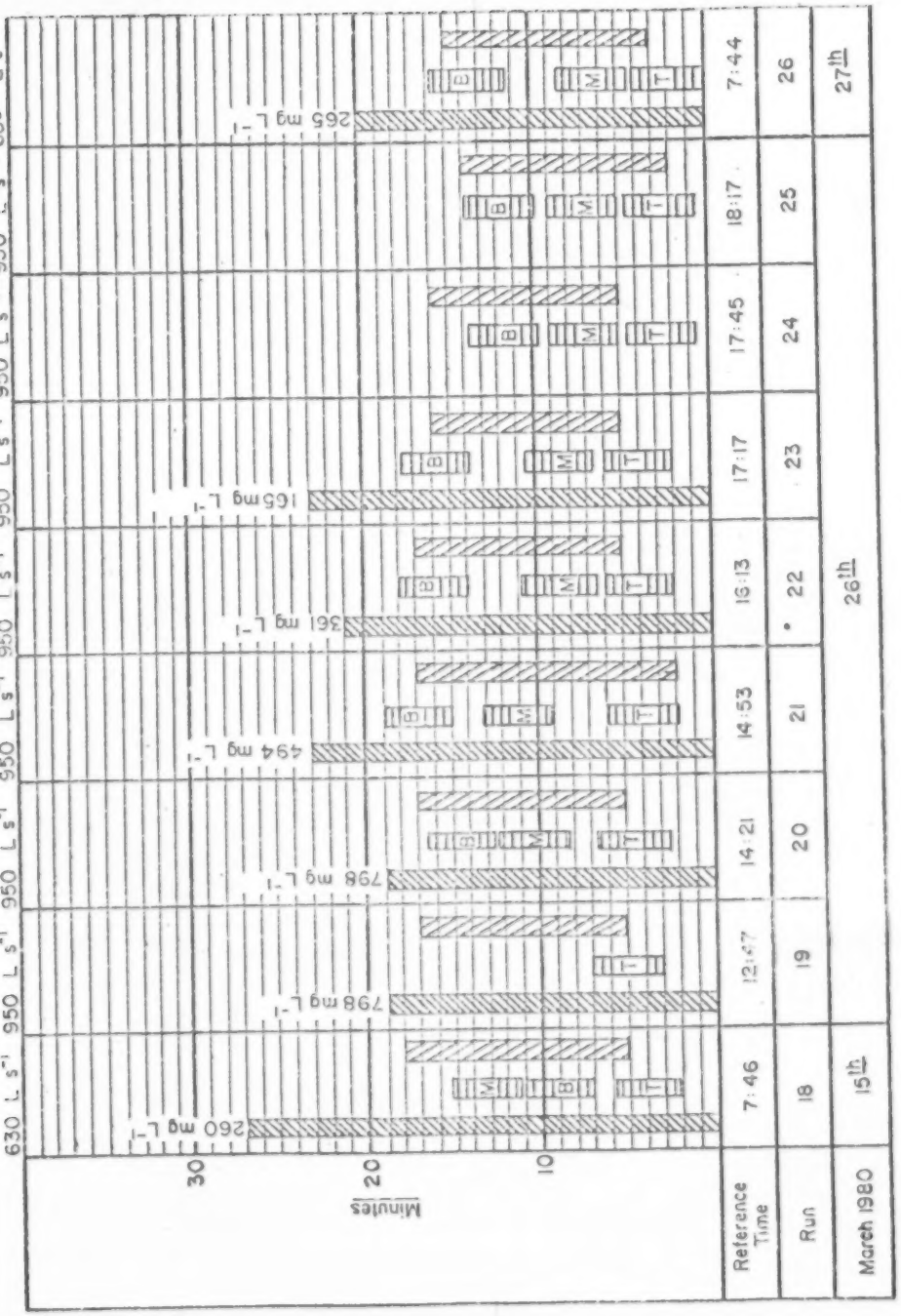


FIGURE 55. CHRONOLOGICAL RECORD OF TEST RUNS (Cont'd)

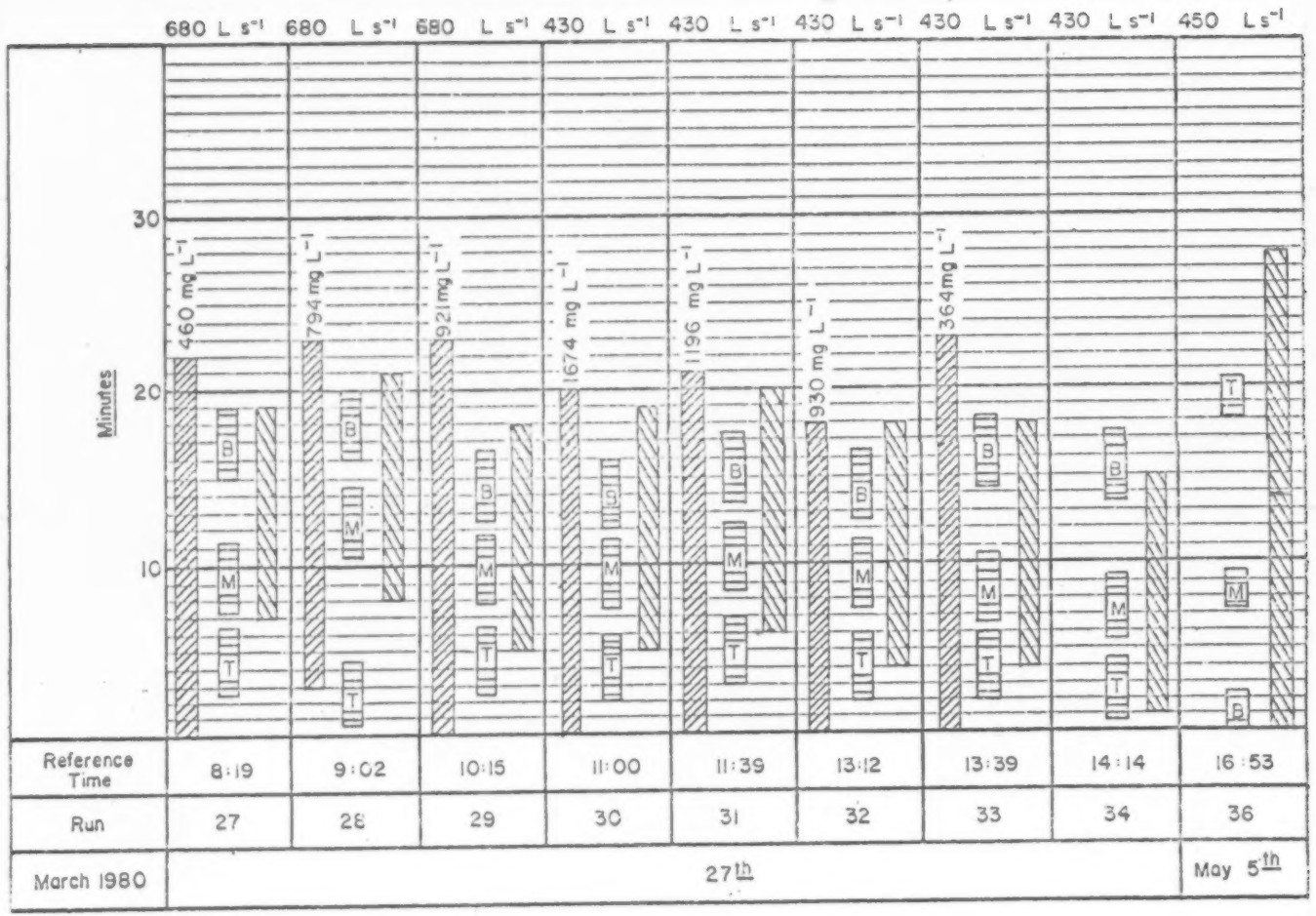


FIGURE 55. CHRONOLOGICAL RECORD OF TEST RUNS (Cont'd)

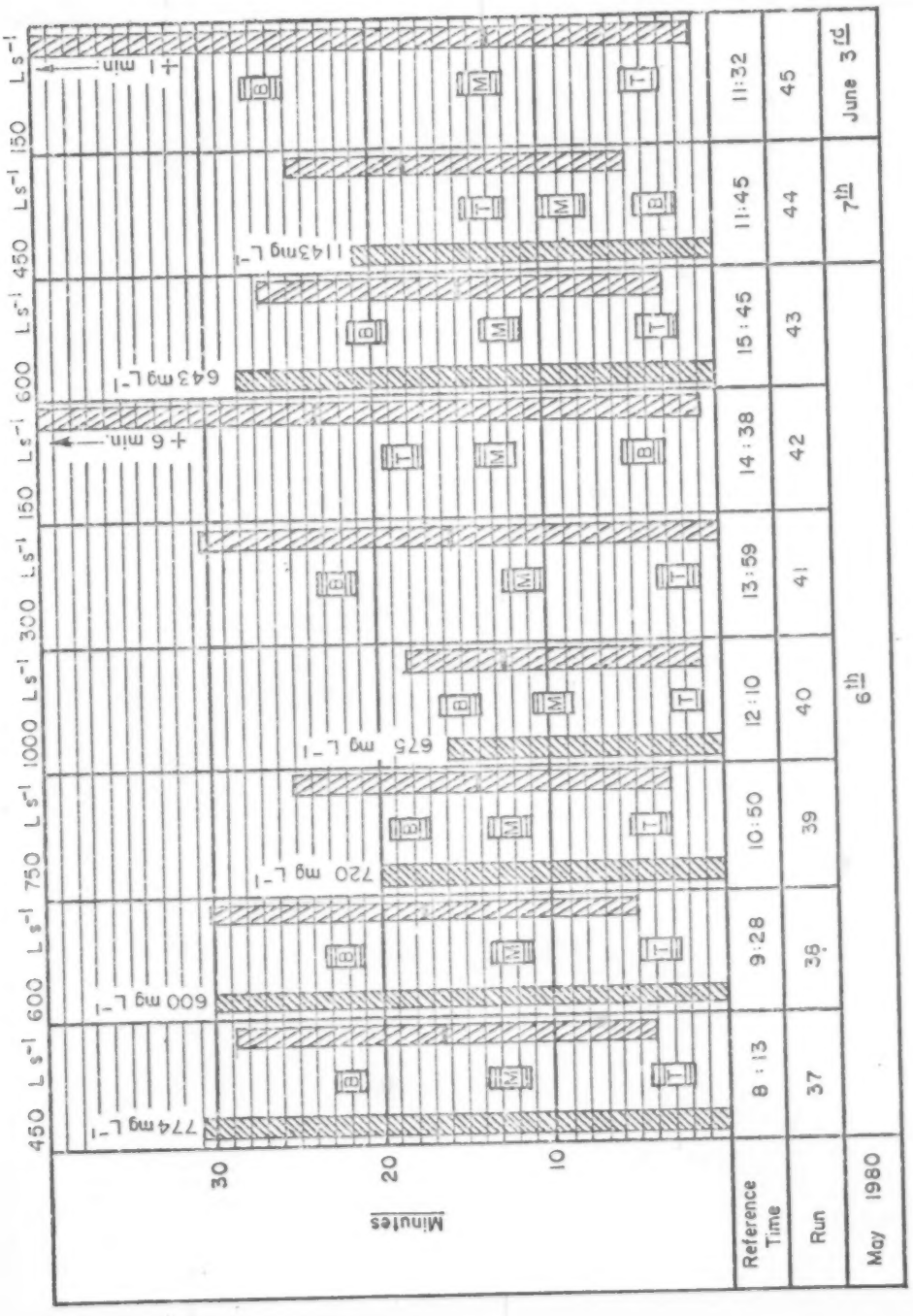


FIGURE 55. CHRONOLOGICAL RECORD OF TEST RUNS (Cont'd)

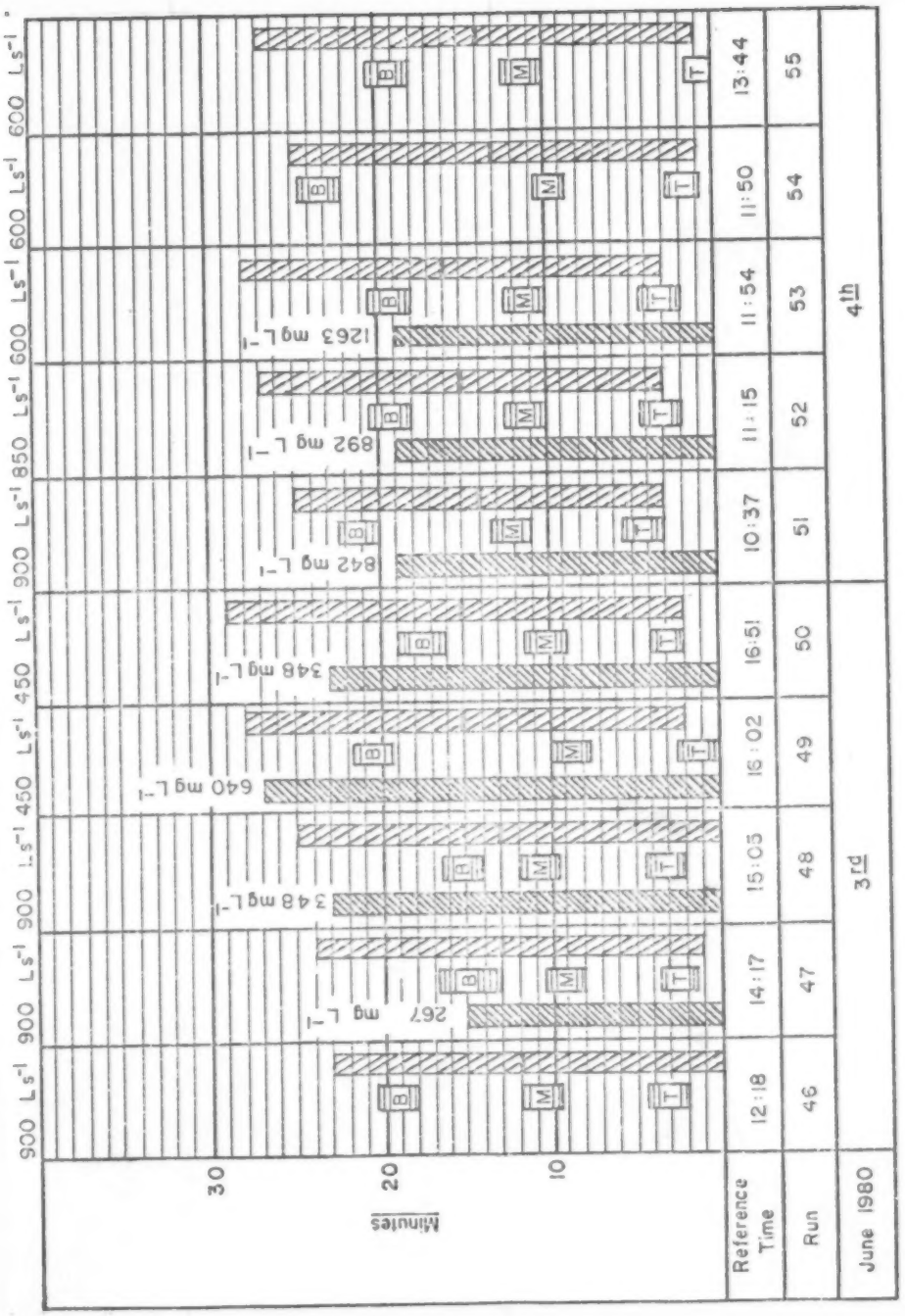


FIGURE 55. CHRONOLOGICAL RECORD OF TEST RUNS (Cont'd)

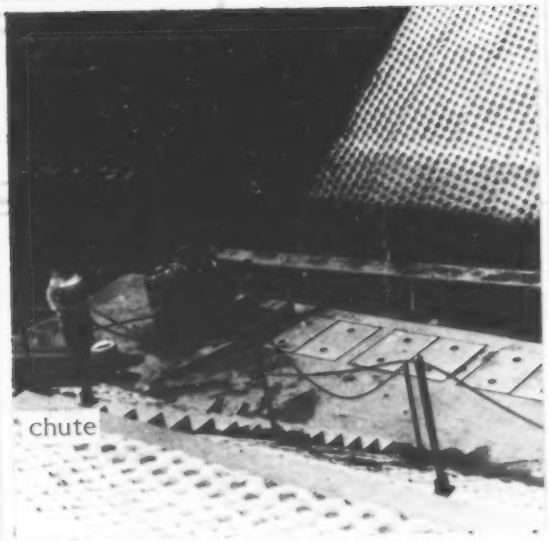


FIGURE 56

River Intake - Sampling Point 1.

FIGURE 57

Swirl Degritter - Inlet after Run 34.

sand settled on invert of conduit

FIGURE 58

Swirl Degritter - Bottom of Hopper with Eductor Pump.

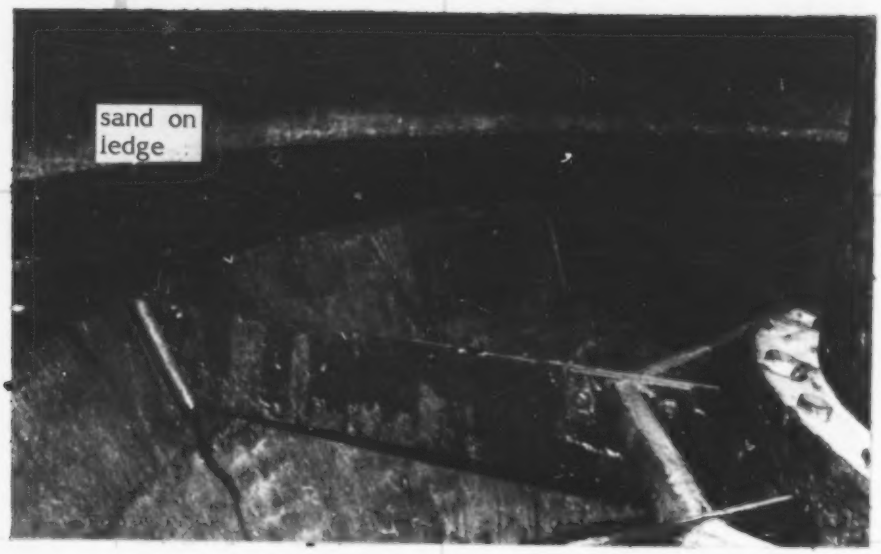


FIGURE 59 Swirl Degritter - Ledge at 45° from Inlet.

FIGURE 60 Swirl Degritter - Ledge at 135° from Inlet.

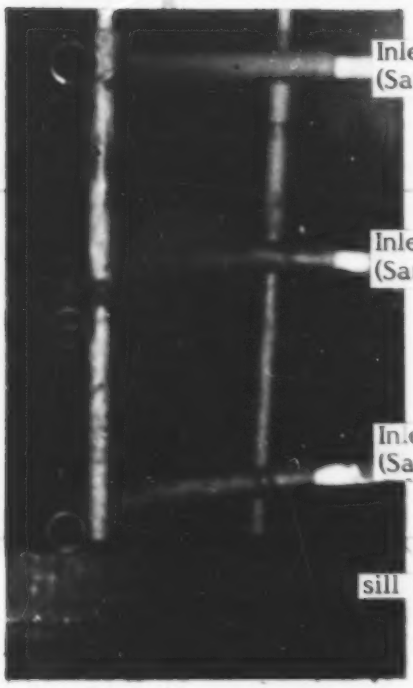


FIGURE 61

Sampling Points 2,3 and 4
(Looking Downstream Towards
Swirl Degritter)

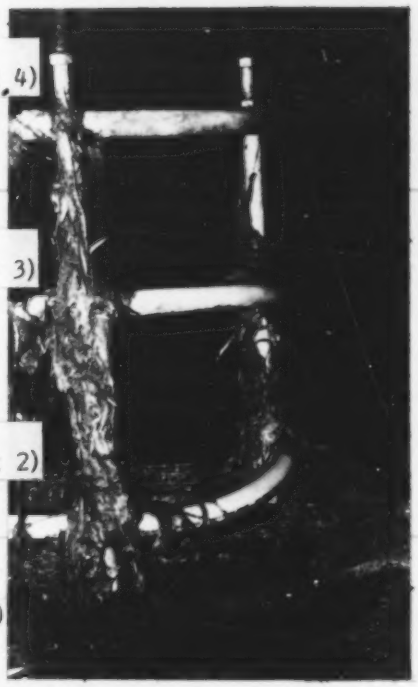


FIGURE 62

Sampling Points 2,3 and 4
(Looking Upstream into
Inlet Conduit)

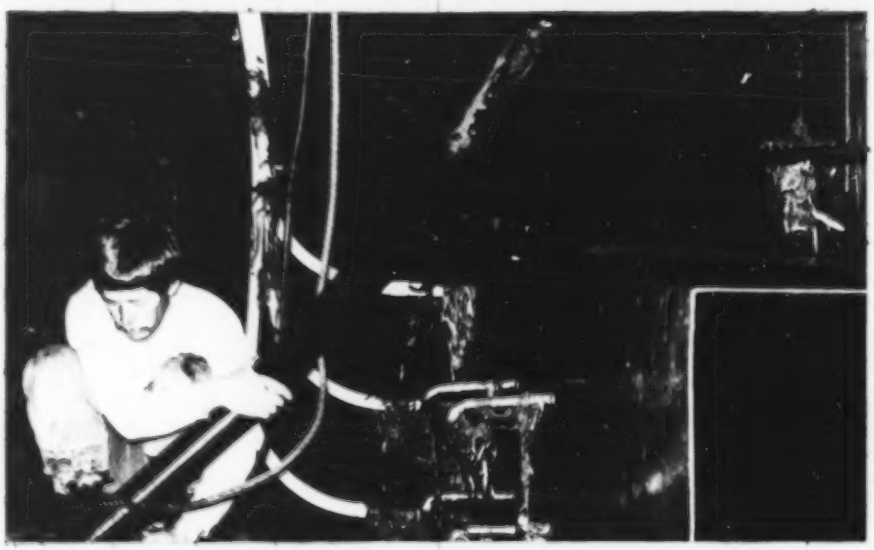


FIGURE 63 Swirl Degritter - Sampling Pipes and Inlet

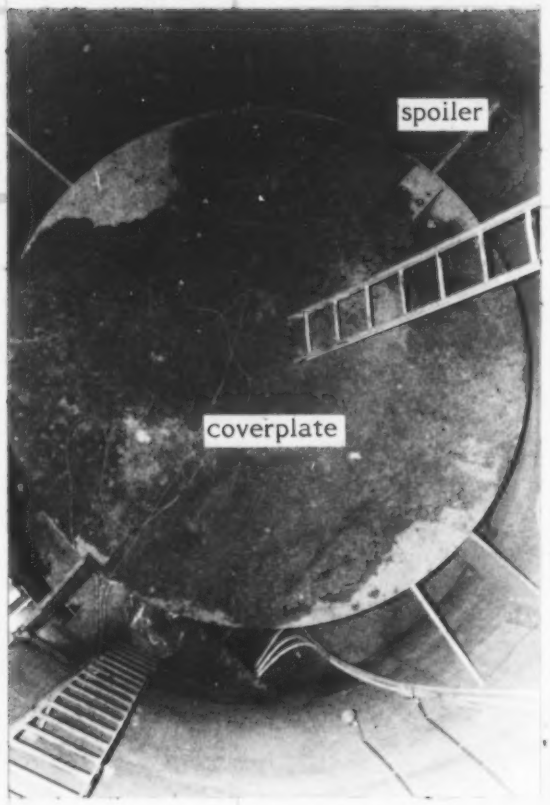


FIGURE 64

Swirl Degritter -
Coverplate and Spoiler
with Sampling Pipes.

sampling suction pipes

water level detector

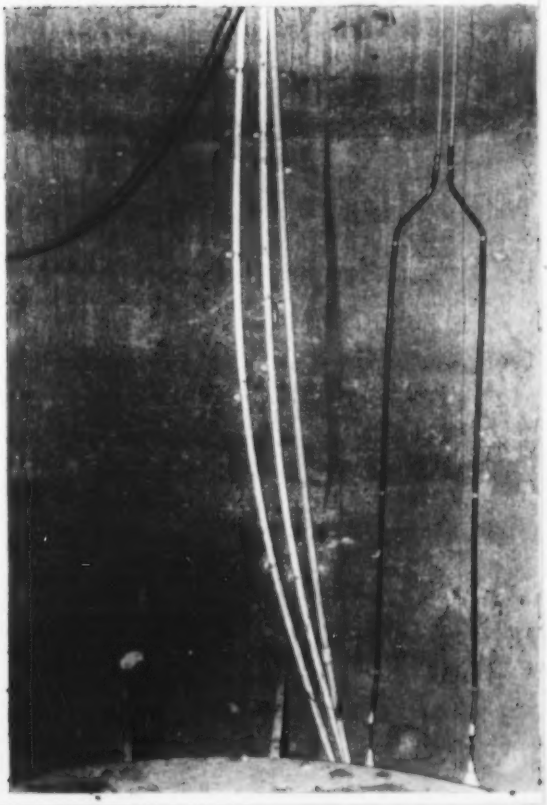


FIGURE 65

Swirl Degritter -
Sampling Pipes and Float Switch

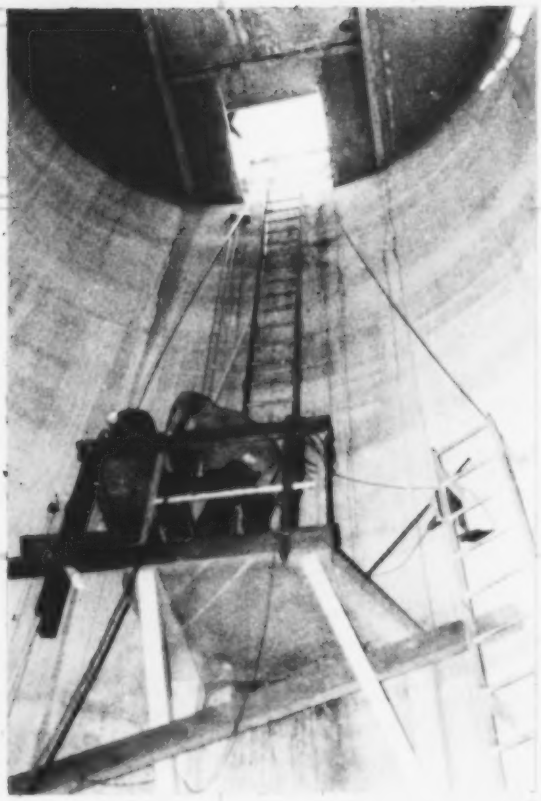


FIGURE 66

Swirl Degritter -
Sampling Pipes and Sampling Pump

sampling discharge pipe

sampling pump

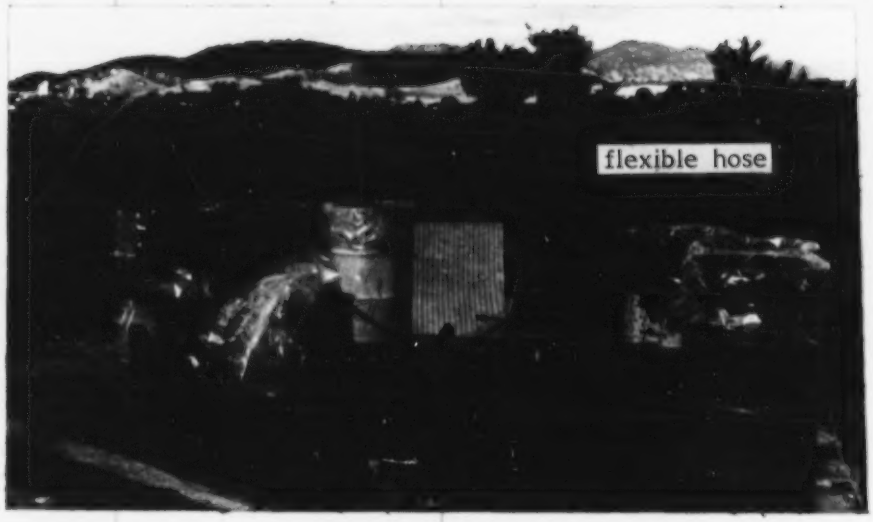


FIGURE 67 Swirl Degritter - Top with 54 gal Drums.

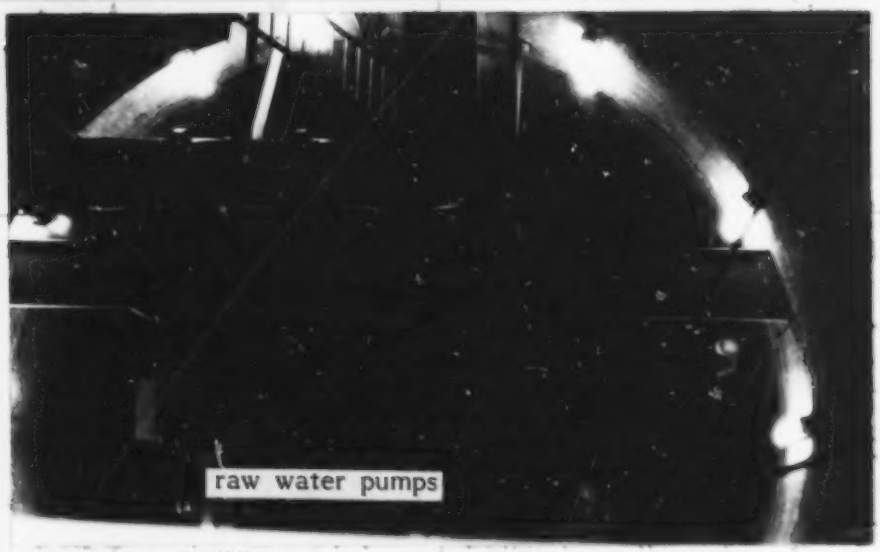


FIGURE 68 Pumping Station - Sampling Point 5 with 54 US gal Drums.

FIGURE 69

Floaters for Decanting Water

Flow rate	Run No.	GRIT ASH					
		Grain size	Influent	Swirl effluent	Influent concentration	Swirl effluent concentration	Removal
		mm	%	%	mg/L	mg/L	%
Actual Q = 0·5 M gal/d (21·9 L/s) Scaled up Q = 6·16 M gal/d (270 L/s) Bases: Tables 6 & A4 (Ref 2)	1	< 0.15	16.4	71.4	3.5	3.45	10.3
		0.15-0.25	24.0	18.1	5.1	0.9	82.7
		0.25-0.5	46.9	8.8	9.9	0.4	95.7
		0.5 -1.0	6.6	1.5	1.4	0.1	94.8
		1.0 -2.0	4.5	0.2	0.9	0	99.0
		2.0 -3.15	1.4	0	0.3	0	100
		3.15 <	0.2	0	0	0	100
		Total 1	100	100	21.1	4.83	76.8
		Total 2	100	100	17.61	1.38	92.2
	2	< 0.15	26.5	81.1	1.5	1.8	14.5
		0.15-0.25	21.3	13.1	1.2	0.3	77.0
		0.25-0.5	23.9	4.1	1.4	0.1	93.6
		0.5 -1.0	13.7	1.3	0.8	0	96.4
		1.0 -2.0	9.2	0.4	0.5	0	98.4
		2.0 -3.15	3.8	0	0.2	0	100
		3.15 <	1.6	0	0.1	0	100
		Total 1	100	100	5.8	2.17	61.9
		Total 2	100	100	4.3	0.37	91.4
	3	< 0.15	8.9	72.9	2.9	2.5	16.4
		0.15-0.25	25.9	20.5	8.6	0.7	91.9
		0.25-0.5	51.3	5.7	17.0	0.2	98.9
		0.5 -1.0	10.6	0.9	3.5	0	99.1
		1.0 -2.0	2.4	0	0.8	0	100
		2.0 -3.15	0.7	0	0.2	0	100
		3.15 <	0.2	0	0.1	0	100
		Total 1	100	100	33.1	3.38	89.7
		Total 2	100	100	30.2	0.88	97.1
	4	< 0.15	19.6	72.8	1.7	1.2	27.0
		0.15-0.25	33.2	17.3	2.9	0.3	89.8
		0.25-0.5	40.3	7.5	3.5	0.1	96.3
		0.5 -1.0	5.3	1.2	0.5	0	95.6
		1.0 -2.0	1.4	0.2	0.1	0	97.2
		2.0 -3.15	0.2	0	0	0	100
		3.15 <	0	0	0	0	0
		Total 1	100	100	8.6	1.69	79.6
		Total 2	100	100	6.9	0.49	93.1
	5	< 0.15	25.1	72.9	0.8	0.6	21.1
		0.15-0.25	23.1	15.3	0.7	0.1	82.0
		0.25-0.5	24.1	8.2	0.8	0.1	90.8
		0.5 -1.0	11.0	0	0.3	0	100
		1.0 -2.0	10.7	1.2	0.3	0	97.0
		2.0 -3.15	5.3	2.4	0.2	0	87.7
		3.15 <	0.7	0	0	0	100
		Total 1	100	100	3.13	0.85	73.5
		Total 2	100	100	2.33	0.25	99.7

Legend: Total 1. Total Solids
Total 2. d> 0·2 mm

FIGURE 70. SUMMARY OF RESULTS AT DENVER, CAL. USA (Ref 2)

Flow rate	Run No.	GRIT ASH					
		Grain size	Influent	Swirl effluent	Influent concentration	Swirl effluent concentration	Removal
		mm	%	%	mg/L	mg/L	%
Bases: Tables 7 & A5 (Ref 2) Actual Q = 1 M gal /d (43·8 L/s) Scaled up Q = 12·3 Mgal /d (540 L/s)	1	< 0.15	11.5	51.0	1.7	3.1	83.5
		0.15-0.25	13.9	26.5	2.0	1.6	21.1
		0.25-0.5	22.6	13.9	3.3	0.8	74.6
		0.5 -1.0	22.9	5.2	3.3	0.3	90.6
		1.0 -2.0	18.2	2.5	2.7	0.2	94.3
		2.0 -3.15	7.7	0.5	1.1	0	97.3
		3.15 <	3.2	0.4	0.5	0	94 8
		Total 1	100	100	14.6	6.04	58.5
		Total 2	100	100	12.9	2.94	77.2
	2	< 0.15	11.6	53.6	6.2	3.0	51.0
		0.15-0.25	18.1	28.5	9.7	1.6	83.8
		0.25-0.5	50.7	10.6	27.1	0.6	97.8
		0.5 -1.0	11.3	3.5	6.0	0.2	96.7
		1.0 -2.0	5.9	2.2	3.2	0.1	96.0
		2.0 -3.15	1.9	0.9	1.0	0.1	95.0
		3.15 <	0.5	0.7	0.3	0	85.2
		Total 1	100	100	53.5	5.67	89.3
		Total 2	100	100	47.3	2.67	94.4
	3	< 0.15	23.4	57.1	4.5	1.9	56.7
		0.15-0.25	14.3	18.9	3.3	0.6	80.7
		0.25-0.5	23.0	13.8	5.3	0.5	91.2
		0.5 -1.0	18.9	5.1	4.4	0.2	96.1
		1.0 -2.0	12.4	3.6	2.9	0.1	95.8
		2.0 -3.15	6.3	1.5	1.5	0.1	96.5
		3.15 <	1.7	0	0.4	0	100
		Total 1	100	100	23.1	3.38	85.6
		Total 2	100	100	17.7	1.48	91.6
	4	< 0.15	14.6	61.5	4.9	5.0	0.8
		0.15-0.25	17.4	25.8	5.9	2.1	64.5
		0.25-0.5	50.3	8.5	17.0	0.7	96.0
		0.5 -1.0	10.1	2.1	3.4	0.2	95.0
		1.0 -2.0	5.1	1.1	1.7	0.1	94.8
		2.0 -3.15	1.7	0.3	0.6	0	95.2
		3.15 <	0.8	0.7	0.3	0.1	79.1
		Total 1	100	100	33.8	8.09	76.0
		Total 2	100	100	28.9	3.09	89.3
Legend: Total 1. Total Solids Total 2. d > 0·2 mm	5	< 0.15	11.4	43.2	6.4	5.0	22.1
		0.15-0.25	19.4	26.7	10.9	3.1	71.7
		0.25-0.5	42.8	16.5	24.1	1.9	92.1
		0.5 -1.0	14.1	8.0	8.0	0.9	88.3
		1.0 -2.0	7.9	4.5	4.5	0.5	88.3
		2.0 -3.15	3.3	0.8	1.9	0.1	95.0
		3.15 <	1.1	0.3	0.6	0	94.4
		Total 1	100	100	56.4	11.59	79.4
		Total 2	100	100	50.0	6.59	86.8

FIGURE 71. SUMMARY OF RESULTS AT DENVER, CAL. USA (Ref 2)

Flow rate	Run No.	GRIT ASH					
		Grain size	Influent	Swirl effluent	Influent concentration	Swirl effluent concentration	Removal
		mm	%	%	mg/L	mg/L	%
Bases Tables 88 A6 (Ref 2) Actual Scaled up Q= 2 M gal/d (87.6 L/s) Q= 24.6 M gal/d (1080 L/s)	1	< 0.15	17.4	23.2	2.7?	2.2	19.5
		0.15-0.25	14.9	17.3	2.4	1.7	29.9
		0.25-0.5	22.0	18.9	3.5	1.8	48.1
		0.5 -1.0	19.5	16.0	3.1	1.5	50.5
		1.0 -2.0	17.2	13.6	2.7	1.3	52.3
		2.0 -3.15	6.7	7.5	1.1	0.7	32.4
		3.15 <	2.3	3.5	0.4	0.3	8.1
		Total 1	100	100	15.8	9.54	39.6
		Total 2	100	100	13.1	7.34	44.0
	2	< 0.25	9.7	18.4	4.9	3.8	21.2
		0.15-0.25	22.4	29.1	11.2	6.1	46.1
		0.25-0.5	47.7	30.2	23.9	6.3	73.7
		0.5 -1.0	12.0	10.5	6.0	2.2	63.7
		1.0 -2.0	5.3	7.6	2.7	1.6	40.5
		2.0 -3.15	2.0	2.8	1.0	0.6	41.9
		3.15 <	0.9	1.4	0.5	0.3	35.4
		Total 1	100	100	50.1	20.8	58.2
		Total 2	100	100	45.2	17.0	62.4
	3	< 0.15	6.9	23.2	3.5	4.8	37.0
		0.15-0.25	11.7	33.4	5.9	6.8	16.3
		0.25-0.5	33.3	36.3	16.7	7.4	55.6
		0.5 -1.0	23.4	4.5	11.8	0.9	92.2
		1.0 -2.0	16.7	2.0	8.4	0.4	95.1
		2.0 -3.15	6.4	0.3	3.2	0.1	98.1
		3.15 <	1.6	0.3	0.8	0.1	92.4
		Total 1	100	100	50.3	20.5	59.3
		Total 2	100	100	46.8	15.7	66.5
	4	< 0.15	8.1	22.9	3.4	3.1	9.8
		0.15-0.25	15.5	31.5	6.6	4.3	35.1
		0.25-0.5	37.7	32.9	15.9	4.4	72.1
		0.5 -1.0	21.4	7.0	9.1	0.9	89.6
		1.0 -2.0	11.7	4.1	4.9	0.6	88.8
		2.0 -3.15	4.2	1.3	1.8	0.2	90.1
		3.15 <	1.4	0.3	0.6	0	93.2
		Total 1	100	100	42.3	13.5	67.9
		Total 2	100	100	38.9	10.4	73.3
Legend: Total 1. Total Solids Total 2. d ≥ 0.2 mm	5	< 0.15	6.4	24.0	0.4	1.1	-192.4
		0.15-0.25	10.0	15.1	0.6	0.7	17.8
		0.25-0.5	33.3	18.2	2.0	0.9	57.4
		0.5 -1.0	25.3	14.6	1.5	0.7	55.0
		1.0 -2.0	17.4	13.5	1.1	0.6	39.5
		2.0 -3.15	5.9	9.4	0.4	0.4	-24.2
		3.15 <	1.7	5.2	0.1	0.2	-138.5
		Total 1	100	100	6.04	4.71	21.5
		Total 2	100	100	5.6	3.61	36.0

FIGURE 72. SUMMARY OF RESULTS AT DENVER, CAL. USA (Ref 2)